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OF THE

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URANIUM RESOURCES OF THE NORTHERN PLAINS

by

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1978

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Research study and report were developed as one element of the Energy Research Project under a grant from the Old West Regional Commission, and in conjunction with the Montana Department of Community Affairs and Action for Eastern Montana.

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CONTENTS

	Page
Preface	x
1. Historical Highlights	1
2. Uranium Lands and Ore Deposits -- National and Foreign	3
A. United States Uranium Reserves	3
B. World Resources	6
C. Uranium Defined and Where Found	6
D. Types of Deposits	9
E. Uranium in Montana	10
F. Thorium Lands and Deposits	14
G. Geology of Uranium Deposits -- Southwestern Williston Basin	16
H. Distribution of Uranium	17
I. Analyses	26
J. Summary of Williston Basin Uranium	26
3. The Peaceful Atom	27
A. Natural Radiation	27
B. Earth's Background Radiation	27
C. What About Radioactivity?	28
D. Fusion Power	29
E. Alpha, Beta, and Gamma Rays	30
F. Nuclear Radiation	30
G. Plutonium	31
H. Midterm Outlook for Domestic Energy	34
I. Upgrading the Generation of Nuclear Power	35
J. Thorium for Production of Energy	36

K. How the "Breeder" Reactor Works..... 37

4. Modern Techniques of Uranium Exploration..... 38

A. The NURE Program..... 39

B. The Lone Prospector..... 40

C. Exploration in the Southeastern Corner of Montana..... 41

5. Authorized Activities and Exploration on Public Lands..... 44

A. Exploration for Minerals on Public Lands..... 44

B. Management Provisions of U.S. Forest Service..... 44

C. Will Uranium Activity Increase on Public Lands of the Northern Plains?..... 46

6. Southeastern Montana and Adjacent-States Uranium Deposits. 48

A. Uraniferous Lignites..... 48

B. Extraction of Uranium..... 51

C. Recent Uranium Developments in Western South Dakota... 52

7. Exploration and Mining..... 54

A. Uranium Exploration Within Long Pines..... 54

B. Wildlife Disturbances..... 58

C. General Impacts..... 59

D. Management Plan..... 61

E. Above-Surface Potential Impacts Associated With Exploration Uranium Drilling..... 61

F. Below-Surface Potential Impacts Associated with Exploration Uranium Drilling..... 66

G. Solution Mining and Potential Impacts..... 67

H. By-Product Mining..... 67

8. Reclamation of Exploration and Mined Sites..... 68

9. Techniques of Uranium Mining..... 70

A. Open-Pit and Underground..... 70

B. Solution Mining..... 73

C. Methods and Benefits..... 76

10. Waste Disposal and Some Safety Aspects of Uranium Development and Nuclear Energy Production..... 79

A. Disposal of High-Level Radioactive Wastes..... 80

B. Underground Mine and Safety..... 81

C. Typical Safeguards and Reclamation as Used at the Shirley Basin Complex..... 81

11. Some Socioeconomic Impacts and Corrective Measures..... 84

A. General Discussion..... 84

B. Assistance to Regions Experiencing Uranium Development..... 87

12. Market Demands and Development..... 89

13. Conclusions..... 91

A. Above-Surface Impacts..... 91

B. Below-Surface Impacts..... 91

C. Monitoring and Regulation of Solution Mining..... 92

D. Higher Prices and Increased Uranium Activity..... 93

E. Uranium Production..... 95

F. Capital Concerns..... 95

G. Production of Nuclear Energy..... 96

14. Literature Cited..... 97

Appendix A -- Uranium Exploration Activity in Carter County..... A-1 to A-3

Appendix B -- Legislation Related to Uranium..... B-1 to B-7

Appendix C -- Companies Involved in Uranium Leasing, Mining Claims, and Water Applications..... C-1 to C-3

Appendix D -- 1872 Mining Law and Some Effects on Public Lands..... D-1 to D-3

Appendix E -- Initial Goals and Current Development..... E-1 to E-5

Appendix F -- Montana Metalliferous Taxation Relative to Uranium..... F-1 to F-19

Appendix G -- Uranium Report to the Governor and the 1977 Legislature by the Department of Natural Resources and Conservation..... G-1 to G-9

Appendix H -- Glossary of Nuclear Energy Terms..... H-1 to H-22

Appendix I -- Nuclear Fuel and Uranium Resources..... I-1 to I-10

ILLUSTRATIONS

Figure		Page
1.	Assessment pit is typical of those dug on Long Pines uranium claims in the 1950's and early 1960's. Annual assessment work is a requirement for continued ownership of a mineral claim.....	2
2.	The effect of structure and permeability on uranium mineralization.....	12
3.	Uranium occurrences in the Chalky Buttes area, Slope County, North Dakota.....	19
4.	The numbered areas (1 to 9) have in the past been studied as to uranium deposits and are discussed herein.....	20
5.	Uranium occurrences in the Long Pines area, Carter County, Montana.....	23
6.	Uranium occurrences in Ekalaka Hills Area, Carter County, Montana.....	25
7.	The fuel cycle associated with one year's operation of a typical 1000-electrical-megawatt nuclear power plant.....	32
8.	Approximate lines of drill holes (1 through 6) that were drilled by Mobil Oil Corporation on the Long Pines during July, 1977.....	43
9.	Location of known uranium deposits in the western United States.....	45
10.	Capitol Rock and the surrounding 240 acres are reserved against development activities. The mineral claims held within this scenic area by a private company were voluntarily relinquished upon Forest Service request.....	47
11.	Uranium deposits of the Northern Plains.....	49
12.	Long Pines access road used by Mobil Oil receives reclamation treatment of native hay mulch to reduce run-off and encourage growth of native vegetation. Group of local planning, county government, and private company personnel are shown during tour of the area.....	57
13.	Dam built by Mobil Oil Corporation provides a roadway for heavy equipment and water for drilling operations.....	62

14. Typical view of reclaimed exploration drill site on the Long Pines Forest. Stake near center of photo marks the drill hole..... 64

15. Cuttings disposal pit..... 65

16. Bare earth in foreground marks location of refilled drill hole. The site was by design left in a non-reclaimed condition as a study and comparison area. This site is on private land..... 69

17. The Highland open-pit uranium mine north of Douglas, Wyoming with pit floor at about 200 feet. Overburden is being removed to uncover ore deposits formerly not considered worth mining..... 71

18. The Lucky Mc uranium mine at Shirley Basin, Wyoming. Man in foreground uses Geiger counter to determine which material goes to spoil pit and which to the processing mill..... 72

19. Typical modern solution-mining operation on roll-front uranium deposit..... 75

20. Complete processing and uranium recovery plant associated with a strip-mining operation..... 77

21. Schematic of uranium recovery plant process associated with a solution-mining operation..... 78

22. An artist's rendering of a pilot plant concept for disposing of solidified high-level radioactive waste. The waste would be stored in salt beds at depths of 1000 to 3000 feet underground. They would be retrievable..... 82

23. The energy available from various resources in the U.S. compared with one projection of the nation's needs between now and the end of the century. (Q is a term that represents a billion billion British thermal units.)..... 94

Appendix Illustrations:

A-1 -- Carter County Uranium Exploration..... A-3
I-1 -- The Light Water Reactor Nuclear Fuel Cycle..... I-2
Map A -- Uranium Lands of the Northern Plains and types of activity

Map B -- Uranium companies and exploration in Carter County

Map C -- Active water wells in Carter County

TABLES

Table 1 -- National Uranium Deposits..... 5

Table 2 -- Regional Summary of Uranium Production; Reserves and Potential..... 7

Table 3 -- Foreign Uranium Deposits..... 8

Table 4 -- Some Uranium-Bearing Areas of Montana..... 10

Table 5 -- Estimated and Proved Energy Reserves..... 34

Table 6 -- Uranium Exploration in the United States..... 40

Table 7 -- Uranium and Coal Prospecting Permits in Western South Dakota..... 53

PREFACE

An extensive and potentially valuable uranium resource region exists within the Northern Plains. The "Uranium Report" assesses this wide region referred to herein as the "uranium lands of the Northern Plains." Specific attention is given the Long Pines Forest of Carter County and adjacent tri-state junction areas (Montana, Wyoming, South Dakota) which provide a representative and convenient focal point for a generalized evaluation of uranium and associated topics.

These uranium resources could initiate construction of new processing plants, enrichment facilities, and one or more mobile-home communities, all within the next 10 to 20 years. This view, however, applies only if the need for nuclear power and its subsequent development proceed to new levels in the near future. The more plentiful and economical energy sources, coal for example, could overshadow or curtail any appreciable increase in development of uranium, especially that portion destined for production of electrical power.

Few now doubt that under selected conditions electricity generated from nuclear-powered steam turbines can be appreciably competitive with that developed from fossil-fueled plants. However, after viewing the shortages, waste disposal problems, and price increases for uranium and nuclear plants, many doubt that nuclear energy will be the primary or sole answer to National energy needs in the foreseeable future. Nuclear energy has not approached a fulfillment of the near-panacea potential promised for it by a few elements of industry during the ebullient post-World War II years and during the peak-publicity era of the "peaceful atom" in the 1950's and the early 1960's.

A fair share of the nuclear enthusiasm of relatively recent years was based on unique circumstances which included: (1) large-scale funding provided by the Government for research and development; and (2) the initial input of suppliers who quoted highly attractive prices for their generating equipment when it seemed essential to the spread of the new technology. These circumstances are unlikely to be repeated during this century in our Nation and, of course, have never applied at any time in the undeveloped countries.

In addition to its more exotic applications, the reputation of nu-

clear power as a compact source of energy reached the world's seawater-desalting projects. But here, too, nuclear energy faced an emerging competitor. Solar power may be favored as an energy source for evaporation-desalination operations, provided the economic and technological feasibility of large-scale desalination projects can be justified in tomorrow's world. Other experiments with nuclear desalination projects are designed to explore joint production of electrical power and potable water in desert areas.

In future decades, nuclear energy may provide more than its current 10 percent of the total electricity produced in our Nation. On the other hand, nuclear-powered steam turbines may give way to improved techniques for converting coal to electrical energy. The increased use of coal and the emerging non-limited natural resources of sun and wind may to some as yet unknown degree eclipse nuclear energy. This could occur before the end of the century. Conversely, some factions of industry believe that nuclear power may accomplish as much as 40 percent of total United States electricity production by year 2000.

Regardless of its share of future electricity production, nuclear energy is almost certain to play an important role in specific applications such as space exploration and projects associated thereto, medicine, high-technology research, and military programs. Furthermore, many critical applications of nuclear energy not yet visible on the technological horizon predictably will emerge, possibly prior to and certainly subsequent to year 2000. Currently (1978) 1 United States and 9 Soviet satellites with either uranium or plutonium units aboard are orbiting the earth. The nuclear-powered unit of the United States is known to be encased to resist impact as a safety measure against accidental re-entry and possible earth collision.

Uranium prospecting across the western United States is primarily aimed at less-valuable and deeper-lying ores because the richer and relatively shallow-lying deposits have been discovered. It is acknowledged that extremely widespread and intensive prospecting activity for uranium both by ERDA and private companies is under way throughout our Nation, but the Uranium Report focuses its attention specifically upon the uranium lands of the Northern Plains. (Map A, at back of report)

At various points in the Uranium Report, the technical statistics

and data may appear to excessively conflict, overlap, or duplicate each other in a non-parallel fashion with no discernible purpose. Such non-parallels have been permitted in the Report in the interest of offering the reader a balanced view of the sometimes rather widely-diverging opinions, fragmentary news material, and varied assortments of data that were combed from a wealth of available sources.

The author has assumed the role of "miner of data" and has specifically avoided the temptation to become a "high-grading screen" for data that fits a preconceived pattern. He has attempted to present data from as many sources as possible under the time and space limits of this Report.

The reader is offered a representative sampling of material so that he can develop personal conclusions in regard to uranium and nuclear energy -- a sometimes controversial subject and nearly always a politically-sensitive and technically-fragmented one. The nuclear field is relatively new and is progressing and changing rapidly. Divergent opinions exist concerning the nature and extent of nuclear power development. Additionally, the secretiveness connected with exploration results often has unavoidably clouded the uranium scene.

No attempt has been made to reconcile each statement of the Report and each bit of data into one homogeneous entity. The author considers it more in tune with the scope and intent of the document to avoid the polishing of each rough data corner. Modifying comments are offered only where essential for purposes of clarity and continuity of understanding.

The general intent is to offer an adequately assembled but not artificially-structured overview of uranium resources and development projects plus a look at the future of nuclear energy on the Northern Plains. The Uranium Report may help residents of the uranium lands understand all of the developable mineral resources underlying their regions. Thus, if they must make choices, decisions, and plans prior and subsequent to construction, development, and arrival of new residents and industry they will have a foundation upon which to base decisions and planning.

Distribution of the Uranium Report includes: Planning Board and County Commissioners in applicable locations; public libraries of eastern Montana; Montana State and Federal research agencies; Montana State Library; Montana's University libraries; State Planning offices of eastern

Montana; Energy Research Centers; North Dakota planning agencies; Old West Regional Commission; Action for Eastern Montana; Department of Community Affairs, etc.

The assistance of those who offered comments, data, and other help is acknowledged and appreciated and their offerings have been incorporated into the Uranium Report where practicable.

Alden F. Kimsey
Glendive, Montana
April, 1978

1. HISTORICAL HIGHLIGHTS

Representing examples of the earliest Northern Plains uranium "strikes," uraniferous lignite was discovered in southwestern North Dakota in 1948 and in eastern Montana in 1949. Early prospecting for uranium in the Long Pines Forest and other Montana regions occurred between 1949 and 1950 and potential commercial deposits in the lignite regions were reported during 1954 to 1955. (Figure 1) Deposits of uranium were soon also found in carbonaceous siltstones and phosphatic claystone beds. In 1953 a carnotite-bearing sandstone was discovered in the Slim Buttes area of northwestern South Dakota. A fairly high-grade uraniferous lignite was subsequently found in the North Cave Hills, also in northwestern South Dakota.

Uranium was discovered farther west in Montana during the late 1940's. Local residents found uranium along the crest of Big Pryor Mountain in Carbon County during the fall of 1955.

The first export of uranium ore from Montana, admittedly not a large operation, occurred in 1949 when secondary uranium minerals were discovered in a siliceous reef structure two miles south of Clancy, which is located south of Helena. Subsequent uranium strikes were made in this same area and uranium ore was shipped to a purchasing depot at Salt Lake City, Utah.

Also, at about this same date (1949) thorium ores were located in the Armstead-Lemhi Pass area of southwestern Montana. Subsequent exploration revealed extremely high-grade thorium elsewhere in Montana.

As of June 1977, the only operation qualifying as even a potential uranium mine in Montana is the planned open-pit and underground mine complex called the Swamp Frog Mine in the Pryor Mountain region. Status of this mine is listed as "developing." Currently (1978) there are no active uranium mines in Montana. *(1)

---

* Numbers in parenthesis refer to references listed under "Literature Cited."

Figure 1. Assessment pit is typical of those dug on Long Pines uranium claims in the 1950's and early 1960's. Annual assessment work is a requirement for continued ownership of a mineral claim.

Other than the Pryor Mountain area, from which commercial grade uranium ore was exported during the 1950's to the 1960's, the primary known uranium resources of Montana are in the southeast corner of the state in Carter County.

The Montana Energy Advisory Council, documenting uranium resources in a report regarding, "A need for Balance: Montana Energy and Growth Policies, January 1977," stated:

> There have been no discoveries of commercial quality uranium ore in Montana. Adoption of solution mining techniques for development of uranium ores may change the definition of "commercial quality" ore. Should this occur....likely areas for discovery of exploitable uranium ore in Montana lie within the Big Hole drainage, the Ruby Valley and the Carbon County quadrant in eastern Montana. Some quantities of pitchblende have been noted in northwestern Montana near the Idaho border."

During the 25-year period from 1947 to 1972, the readily-mined deposits of uranium discovered in our Nation totalled 514,000 tons, for an average of 20,500 tons per year. *(IUS)

2. URANIUM LANDS AND ORE DEPOSITS -- NATIONAL AND FOREIGN

A. United States Uranium Reserves

For purposes of simplicity this report avoids use of definitions as to boundaries relating to National Forest lines and district boundaries, etc, as well as specific land descriptions (i.e. township and range, except where absolutely essential to a discussion).

The principal Northern Plains areas under discussion and their nomenclature for purposes of this report follow: (1) the area referred to as "Long Pines" is the 69,997 acres within the stated boundaries (Map A); (2) the area designated as "southeast corner of Montana" includes Area (1) and lies totally in Carter County southeast of a line drawn

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*Material deemed accurate, reliable, and worthy of usage but not officially quotable because it is pending publication, or of a non-official nature, or otherwise not available for quotation, is designated herein as Informal Unpublished Sources (IUS).

roughly from Mill Iron to Hammond; (3) the area designated as the "uranium lands of the Northern Plains" includes all of area (2) plus approximately a 30-mile strip across the western edges of North Dakota and South Dakota, including Belfield, Edgemont, Black Hills region, Slim Buttes, and Cave Hills (National Forest areas) north of Buffalo, plus the eastern one-half of Wyoming, i.e. including the Shirley Basin and Douglas areas. (Map A)

Generally the uranium lands, as defined and discussed herein, cover eastern Montana, the eastern half of Wyoming, and western rims of South Dakota and North Dakota, as detailed above.

As of 1946, the Atomic Energy Act defined atomic source material as, "Any material which contains 1/500 (0.05 of one percent) or more, of uranium or thorium or a combination thereof."

The deposits of thorium discovered in the Armstead-Lemhi Pass area of southwestern Montana (1949) are worthy of development if a market becomes available. Commercial production has been accomplished on both uranium and thorium in the United States and has occurred in the following types of deposits: vein; replacement deposits in sediments and in limestone; thorium in crystalline rocks. Uranium deposits in the United States as of 1957 are shown in Table 1. (2)

Actual known reserves of discovered and defined uranium ore in the United States may be as high as 640,000 tons of U_3O_8. (IUS) It is estimated that the total of these reserves of U.S. uranium is no lower than 480,000 tons.

Potential United States resources (i.e. those that are currently not discovered and inadequately defined) are stated at 1,060,000 tons of uranium.

In the United States there are a total of 60,000 tons of uranium reserves available from by-product processing. (IUS)

Thus, the total of United States reserves in all three categories, (known reserves; potential reserves; by-product) totals 1,760,000 tons of uranium oxide (U_3O_8).

The total of Free World known uranium reserves, plus this United States portion, reach an estimated 2.4 million tons of U_3O_8.

Potential uranium reserves of the world, including the United States, total 5.1 million tons.

Thorium resources lack adequate appraisal because of the relative lack of interest in development of thorium. However, available estimates indicate 500,000 tons of thorium resources in the United States and around 2,450,000 tons in the world. (IUS)

Contrary to the commonly-accepted idea that all of the large uranium deposits have been discovered, the *OECD-IAEA report indicated that large areas of the world have yet to be explored for uranium and the possibility exists that much more uranium will be discovered in the upper portions of the earth's crust. However, if such deposits do remain, they will be more difficult to locate than earlier-discovered deposits.

Table 1. National Uranium Deposits (Prior to 1957)

Date	Location	Type of Deposit
1947	White Canyon, Utah	**- -
1948	Beaverlodge Lake Area, Canada	Vein Deposit
1949	Marysvale Area, Utah	Vein
1950	Jackpile Deposit, New Mexico	Sedimentary
1950	Monument Valley, Arizona	Sedimentary
1951	Black Hills, South Dakota	Sedimentary
1952	MiVida Mine, Moab, Utah	Sedimentary
1952	Delta Deposit, San Rafael Swell, Utah	Sedimentary
1953	Blind River Area, Canada	Disseminated
1954	Uraniferous Lignite, South Dakota	Sedimentary
1954	Spokane Indian Reservation, Washington	Contact
1955	Ambrosia Lake Area, New Mexico	Sedimentary
1955	Mount Spokane Area, Washington	Vein
1955	Pryor Mountain Deposits, Montana	Replacement in Limestone
1956	Little Mountain Area, Wyoming	Replacement in Limestone

* OECD. Nuclear Energy Agency and International Atomic Energy Agency. 1976. Uranium: Resources, Production and Demand.

** No data available

B. World Resources

Estimated world resources of uranium (Free World nations) ranged from 1 to 2 million tons in 1957, which in 1957 dollars could be produced to yellowcake at only $10 per pound. United States uranium resources as of January 1976 are shown in Table 2.

As early as 1957 it was realized that uranium for future energy production, if such was feasible at all, might have to come from the extensive National deposits contained in uraniferous phosphates and shale. Although the uranium content was low (by 1957 standards), these low-level sources totaled 5 million to 6 million tons of uranium ore of potential commercial value, and the world resources derivable from similar rocks were estimated as being equal to or greater than the known United States deposits. More recent data, offered elsewhere herein, indicate that shale and similar sources are too low-content to afford any reasonable uranium production at this time (i.e., 1978).

The widely-available black shales and granite contain less than 0.01 percent U_3O_8 with cost of production estimated at more than $500 per pound of U_3O_8. Although new technologies could modify the value of these materials, development of them is not considered likely prior to year 2010. (IUS)

As in the United States, uranium exploration is proceeding at an increased rate in foreign countries. However, the same constraints that are observed on the domestic scene may also be curtailing production of uranium in foreign countries. It is possible that the United States can import uranium from South Africa, France, Niger, Gabon, and other locations up into the 1980's. Nevertheless, it is unlikely that the United States can depend upon foreign sources to fill the expected gap between consumption of uranium and need for additional ore deposits between now and the end of the century.

Canada in addition to fully supporting its own nuclear programs may also supply countries such as West Germany and Japan with uranium. Conversely, Australia and South West Africa do not appear to offer large-scale production of new uranium resources. Table 3 shows foreign deposits prior to 1957. (2)

C. Uranium Defined and Where Found

Defined technically as a lithiophilic element, uranium occurs

Table 2. Regional Summary of Uranium Production; Reserves, and Potential as of January 1976. *(ERDA-GJO-108(76)

Region	Tons U_3O_8 (produced at $30/lb.)		
	Production (to 1-1-76)	Reserves (1-1-76)	Probable
Colorado Plateau	197,800	326,000	433,000
Wyoming Basins	59,200	233,100	313,000
Coastal Plain	8,300	43,900	100,000
Northern Rockies	4,800	20,100	27,000
Colorado and Southern Rockies	6,400	9,000	44,000
Great Plains	3,500	6,300	26,000
Basin and Range	1,400	1,400	106,000
Pacific Coast and Sierra Nevada	<1,000	200	10,000
Central Lowlands	<1,000	0	1/
Appalachian Highlands	<1,000	0	1/
Columbia Plateaus	<1,000	0	1/
Southern Canadian Shield	0	0	1/
Alaska	<1,000	0	1,000
Totals	286,400	640,000	1,060,000

1/ Resources not estimated because of inadequate knowledge.

* Uranium Industry Seminar. A National Plan for Energy Research, Development and Demonstration.

< Less than.

Table 3. Foreign Uranium Deposits (Prior to 1957)

Date	Location	Type of Deposit
Uranium First Discovered in 1915	Shinkolobwe, Africa Belgian Congo	Radium-Uranium
Radium, 1921	100,000 tons of radium-uranium-bearing ore was mined and shipped to refining in Belgium	- -
1930	Great Bear Lake, Canada Two types of pitchblende with different ratios of uranium dioxide (UO_2) to uranium trioxide (UO_3).	Veins to depth of 1,800 feet
* --	Beaverlodge Lake, Canada, Ace Mine	Pitchblende St. Louis Fault
1953	Blind River, Canada Uranium content of 2.0 to 2.5 pounds or uranium per ton of ore.	Ore-bearing sediments
- -	Northern Territory, Australia. Principal uranium mineral in saleeite, which is similar to autonite both in appearance, fluorescence, and chemical structure.	- -

* No data available

typically in the upper crust of the earth's surface, where it's average abundance is about four ten-thousandths of one percent (0.0004). The average percentage of uranium in deposits that were being exploited (1957) was about 250 times that of the average rock occurring in the earth's crust. The ubiquitous character of uranium is well known from its many occurrences in a great variety of host rocks. Uranium combines with as many as 20 other elements to form chemical compounds and is an essential element in about 100 minerals and a minor one in another 100.

Uranium is associated with thorium in many minerals. Uraninite pitchblende, and coffinite are commonly found in unoxidized uranium ores. Deposits near the surface exhibit minerals such as carnotite, tyuyamunite, torbernite, autunite, and uranophane.

D. Types of Deposits

Character of United States Uranium Resources

The post-Permian clastic sediments, deposits in continental basins, contain over 95 percent of the United States uranium ore reserve. Ground waters deposited the uranium in the form of roll-fronts or tabular lenses depending on their morphology. The considerably less frequent deposits occur in epigenetic vein types of bodies.

Low-level concentrations of uranium occur in phosphatic ores of Florida. Other by-product uranium sources occur in the leach liquors used in producing copper ores in the western states. However, any production from low-level sources such as these is unlikely (i.e. in 1970's).

Primary Uranium Minerals

The most common primary mineral of uranium is pitchblende, which is usually black, very heavy, and not normally found in surface rock. On the surface it typically weathers into a brightly-colored secondary uranium mineral.

Secondary Uranium Minerals

Occurring in nearly any kind of rock, the secondary radioactive minerals are generally bright green, yellow, or orange in color. They may in some instances be associated with pitchblende. In vein deposits they occur either as crystals or a coating of powder on the fracture-surface of the rock. Certain ones of these secondary minerals will

fluoresce under ultraviolet light, showing a bright yellow or apple green.

Sedimentary Uranium Deposits in Rocks

Most of the uranium being mined in the United States today is found in sedimentary deposits in sandstone, mudstone, and limestone. The sedimentary rocks on the eastern front of the Cordilleran Mountain are mined for uranium in Colorado, Wyoming, and the Dakotas. The deposits occur in an alternating series of folded mountains and asymmetric basins. Individual deposits range from a few pounds to single deposits of 100,000 tons, with the latter representing only about 10 percent of all deposits. (Figure 2)

Most of these highly-productive uranium deposits are in terrestrial rocks and are found in sandstone, but one area near Grants, New Mexico has a potential for production from limestone rock.

Placer Deposits

Minor placer deposits of minerals containing uranium have been worked (as of 1957) in Idaho and North and South Carolina.

E. Uranium in Montana

Montana uranium areas known as early as 1957 are tabulated in Table 4, below.

Table 4. Some Uranium-Bearing Areas of Montana (1957)

Area	Type of Deposit	County
1. Saltese	Vein	Mineral
2. St. Regis	Vein	Mineral
3. Trout Creek	Pegmatite	Sanders
4. Rock Creek	Vein	Granite
5. Boulder Creek	Contact & Vein	Granite
6. Mondarch Creek	Vein	Powell
7. Rimini	Vein	Lewis & Clark
8. Clancy	Vein	Jefferson
9. Winston	Sedimentary	Broadwater
10. Boulder-Basin	Vein	Jefferson
11. Price Gulch	Vein	Silver Bow

Area	Type of Deposit	County
12. Homestake	Vein	Jefferson
13. Whitehall	Vein	Jefferson
14. Camp Creek	Vein	Madison
15. Idaho Creek	Vein	Madison
16. Shoddy Springs	Sedimentary	Jefferson
17. Boulder River	Pegmatite	Sweet Grass
18. Red Lodge	Contact	Carbon
19. Bridger	Sedimentary	Carbon
20. Long Pines Hills	Sedimentary	Carter
21. Baker	Sedimentary	Fallon
22. Pryor Mts.	Sedimentary	Big Horn & Carbon

Potential for uranium production from Montana deposits in 1978 is promising, but has not yet been realized. Uranium of better than average grade has been produced in Montana, but was not found in significant quantities. However, the possibility of commercial production was viewed as promising, even in 1957, with relatively large deposits already discovered and trace amounts evident across the entire state.

Interestingly, the two primary geological formations of Montana, mountainous and plains, each has its own characteristic type of uranium deposits; both the south-centered and eastern plains contain logical locations for sedimentary deposits.

In the 1950's a 20-ton shipment assaying on the order of 6 percent uranium was shipped from the Big Pryor Mountain area. This may have been a record shipment as to high percentage of uranium. (2)

Boulder Batholith

Composed mostly of quartz monsonite, the Boulder Batholith nevertheless is commonly regarded as consisting of "granite." It is 60 miles long and extends essentially from south of Helena to 20 miles south of Butte. Overall, it measures 60 miles long and 20 miles wide. Uranium deposits are mostly in the granite rocks in the northern half of the Batholith. The deposits are associated with the so-called silicious reefs and in the base-metal mineral deposits.

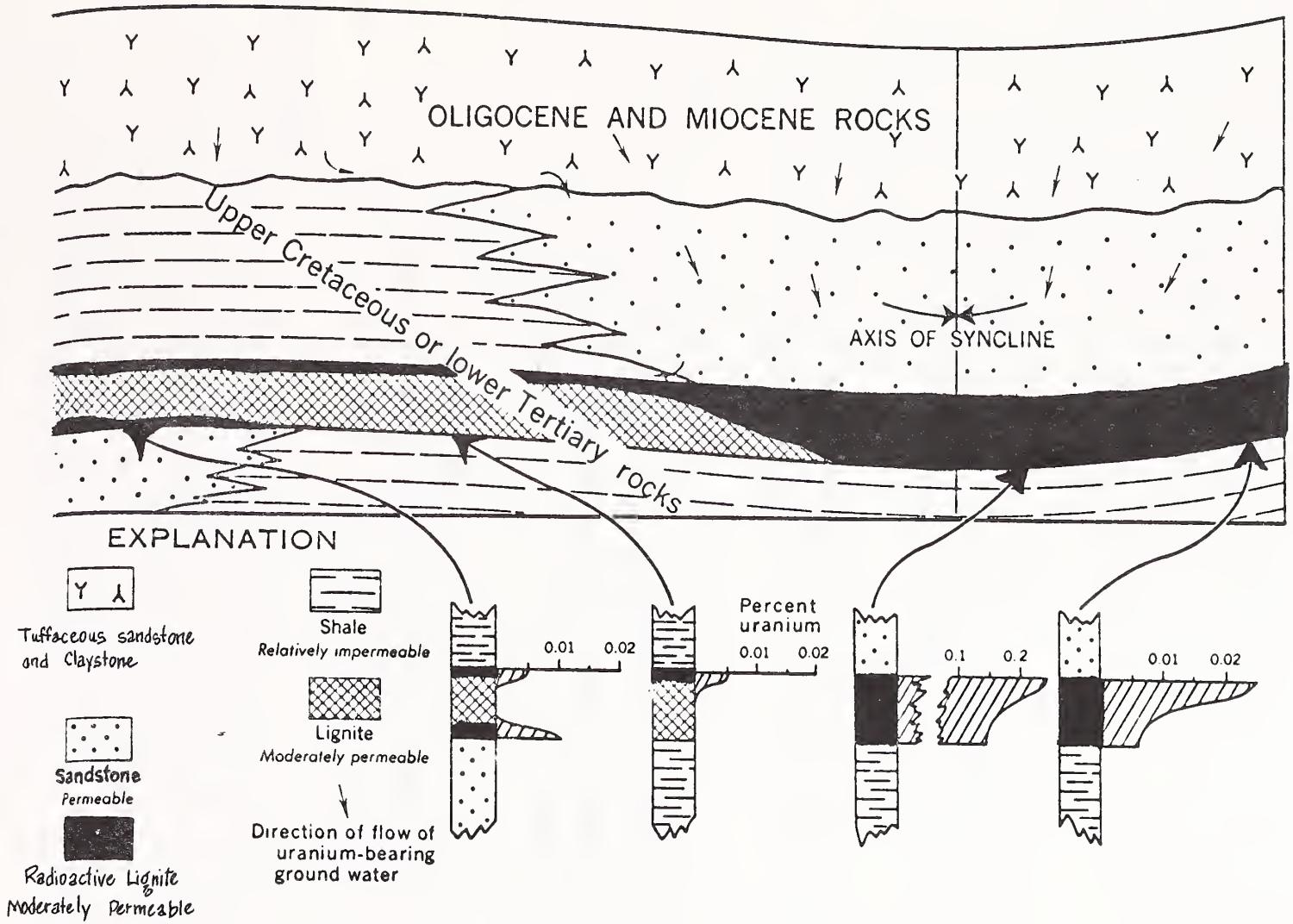


Figure 2. The effect of structure and permeability on uranium mineralization. (From: U.S. Geological Survey)

Alhambra Group

This group contains claims known as the President Group, which consists of about 60 unpatented mining claims located two miles south of Clancy, Montana. During the period of 1951 to 1954, about 700 tons of uranium ore, averaging 0.05 percent, were produced from the W. Wilson claim, from the series of veins classified as silicious reefs. These views are composed of closely-spaced fractures containing cryptocrystalline quartz and cemented breccia. Ore minerals include autunite, torbernite, uranophane, gummite, and uraninite along with several less common uranium minerals. Other associated minerals are pyrite, molybdenite, and galena.

Although commercial-grade ore exists in the Washington and the President reefs, mining operations have not been undertaken. On both of these reefs, vein structure and mineralization are identical with the W. Wilson claim.

Additional claims in the Clancy-Boulder area exhibit similarities to the President Group but they, too, have had little work accomplished.

Winston Area

In 1955 on the east flank of the Spokane Hills, several uranium deposits were discovered. These deposits are of volcanic origin, high in quartz, and contain carbonaceous material such as leaves, twigs, and branches. At any locations exhibiting uranium, this carbon-bearing material is also present.

From the richest of the Winston deposits, two railroad cars of uranium ore were shipped to Salt Lake City, Utah. However, the ore was judged to be less than ore grade, which ended the mining operations.

Mineral County

Near Saltese, in western Montana, uranium was discovered in the St. Regis quartzite. Autunite occurs as thin mica-like coatings on fracture surfaces of the rock. Percentage of uranium is insignificantly small, but rare samples have shown over 0.20 percent uranium oxide (U_3O_8). The Atomic Energy Commission sponsored 200 feet of exploration in this specific area.

West Fork, Bitterroot Mountains

In southern Ravalli County, opposite the mouth of Deer Creek, and

adjacent to the West Fork of Bitterroot River, uranium ore was discovered in 1956. Secondary minerals existing as gummite and uranophane are present and have shown over 1 percent uranium oxide. The minerals exist as narrow veinlets and coatings on fractures along near-vertical faults.

Beartooth Mountains

Small, localized areas along the Boulder River south of Big Timber show above average radioactivity. However, no strikes of uranium ore have been discovered.

Pryor Mountains in Carbon County

Big Pryor Mountains is a portion of the fault related to a series of faults known as the Nye-Boulder lineament, which extends from Nye to 75 miles east and slightly south of Dryhead. At the southeast end of this structure four faults have formed the Pryor Mountains with the separate blocks known as West Pryor, Big Pryor, Northeast Block and East Pryor. Thus far (1957) the major uranium occurrences have been discovered on Big Pryor Mountain. Even more extensive strikes have been made just south of the Montana State line.

In the Pryor Mountain area, uranium occurs in the Madison limestone of Mississippian age, with deposits being typically found in the upper 200 to 250 feet of this formation. Most of the deposits range from 100 to 1,500 tons in total quantity. One large deposit on Little Mountain, Wyoming probably totals 10,000 tons. (2)

F. Thorium Lands and Deposits

Thorium is similar to uranium in potential energy applications, but does not have a natural fissionable isotope as does uranium. Used in a breeder reactor, thorium can be changed into a form of uranium which can be used for atomic energy applications.

In earlier days thorium was used for manufacture of gas mantles. Today, a new use could be in atomic energy applications. Thorium occurs in significant quantities, but due to the limited current applications there has been less interest in thorium exploration than is true for uranium. A point of interest lies in the fact that thorium ore is more plentiful than uranium ore.

Thorium Resources

Admittedly based on limited information, the current estimate of

potential United States thorium resources is 500,000 tons, with about 152,000 tons of this considered as being recoverable, either as a by-product or from primary materials rated at about a 0.1 percent grade.

Thorium is four times as plentiful in the earth as is uranium. Lack of interest has resulted in relatively few statistics on thorium resources. A limited source of thorium is represented by rare earths production from monazite concentrates (ThO_2, 3 to 9 percent); from heavy mineral sands (both in the U.S. and in foreign countries). At present (1978), demand for thorium only reaches about 50 tons per year with a large portion of the ThO_2 now being stored. (IUS)

Thorium Deposits in Montana

Several placer deposits of thorium occur in Montana and vein-type deposits are also available for potential commercial development. However, no ore deposits have yet been exploited in Montana.

Areas of Montana displaying significant deposits of thorium include: Lemhi Pass, Beaverhead County; Townsend-White Sulphur Springs; Deer Creek, Beaverhead County; and Rocky Boy Indian Reservation, Hill County.

The radioactive minerals discovered in Montana in 1949 at Lemhi Pass were probably thorium mistaken for uranium. Selective mining of such deposits might provide materials with 0.50 percent thoria. In actual practice, some of these deposits have been explored and indicate that commercially-feasible ore production would assay close to 1.0 percent thoria.

In the Deer Creek area, thorium deposits range up to 12 feet in thickness and 100 feet in length. Samples of the material generally exhibit less than 0.10 percent thoria, with one deposit showing an assay of up to 2.0 percent thoria. (2)

The Rocky Boy vein deposit located 25 miles south of Havre is no more than a few inches in width and has been explored up to 100 feet underground. Some parts of this deposit may offer up to 0.25 percent thoria.

Placer deposits of thorium include the vicinity of Roundup west to Harlowton and northwest almost to Great Falls and Choteau. At Devil's Basin, 20 miles north of Roundup, a private company operation explored thorium-bearing material measuring from 2 feet to 10 feet thick. The

work was discontinued prior to any commercial production of ore.

G. Geology of Uranium Deposits-- Southwestern Williston Basin

The material in this section offers a historical overview and a baseline of data (1965) for uranium resources in the Williston Basin portion of the Northern Plains. (3)

Analysis on Lignite

Analysis of 10 large samples of uranium-bearing lignite and carbonaceous shale originating in Billings County, North Dakota were conducted by the Atomic Energy Commission (now the Nuclear Regulatory Commission) indicated an average content of 0.18 percent uranium, 0.3 percent molybdenum, 0.09 percent phosphorous, and 0.01 percent vanadium. Of these 10 large samples, only 2 contained less than 0.1 percent uranium, which by today's standards is considered mineable ore if the occurrence is extensive.

Pierre Shale

The Pierre Shale, named for surface exposure at old Fort Pierre in Stanley County, South Dakota, exists as a subsurface formation throughout eastern Montana and the adjacent portions of North and South Dakota.

Composed of brownish-black bentonitic claystone and shale, this formation contains limestone concretions and thin beds of bentonite.

Typically, the Pierre Shale is overlain by the Fox Hills Sandstone and underlain by the Niobrara Formation, both of Late Cretaceous age.

The Pierre Shale does not contain beds of lignite or carbonaceous shale which might contain uranium and consequently has not been mapped in detail (as of 1965). (Fox Hills Sandstone Formations, lying above the Pierre Shale, have been heavily explored for the roll-front uranium deposits.)

Fox Hills Sandstone

The Fox Hills Sandstone is named after the exposures of Fox Ridge located in southwestern Dewey County, South Dakota. The formation exists on top of the Pierre Shale. Rocks of the Fox Hills are a marine sandstone which at many points grade into overlying continental deposits of the Hell Creek Formation and into the underlying marine shales of the Pierre. The formation ranges from 25 to 300 feet in thickness.

Hell Creek

Rocks exposed on Hell Creek and nearby tributaries of the Missouri River in Garfield County in northeastern Montana gives this formation its name. The Hell Creek overlies the marine Fox Hills Sandstone and underlies the lignite-bearing Ludlow member of the Fort Union Formation. Average thickness of the formation is about 500 feet. In the Williston Basin the formation is exposed over wide areas on the flanks of the Poplar dome, the Cedar Creek anticline, and north end of the Black Hills uplift.

Occurrences of lignite and carbonaceous shale have been noted in the Hell Creek but are of little or no commercial value.

Fort Union

The Fort Union Formation is named for rocks exposed near the confluence of the Yellowstone and Missouri River near the site of the Old Fort Union in northwestern McKenzie County, North Dakota.

In the regions of eastern Montana and western North Dakota and South Dakota, the Fort Union consists of about 1,500 feet of lignite-bearing sandstone, shale, and claystone which overlie the Hell Creek Formation. (3)

H. Distribution of Uranium

Studies of the radioactive zones in the Pierre Shale in the southern and western portions of the Williston Basin indicated that the uniform distribution of uranium (averaging 0.0015 percent in the radioactive zone) was due to an increase in the uranium content of the seawater after the deposition of volcanic ash, which has more recently become reformed into bentonite. (3)

In the Williston Basin, in areas where the carbonaceous rocks contain relatively significant amounts of uranium, the uranium minerals generally coat bedding places and joints that intersect the deposit.

Located in west-central Billings County and northwestern Stark County of North Dakota, the Little Missouri River escarpment figured prominently in original uranium discoveries. The escarpment extends for 35 miles on the east side of the Little Missouri River. Most of the uranium-bearing lignites crop out along this escarpment. Low-grade uranium was discovered here in 1948. In 1954, 15 miles east of Bullion Butte in the vicinity of Rocky Ridge, local prospectors discovered uranium ore of potential commercial value. The general region of the escarpment

contains some of the most important uranium deposits in the Williston Basin. (Figures 3 and 4)

Uraniferous lignite and carbonaceous shale occur in important deposits along the Little Missouri River escarpment and are present only in the upper 200 feet of the Sentinel Butte Member of the Fort Union Formation. These deposits occur 2,000 to 2,100 feet above the top of the Pierre Shale principally adjacent to Rocky Ridge (T. 137 N., R. 100 W., and near Saddle Butte, T. 141 N., R 99 W).

These beds of lignite along the escarpment range from 6 inches to around 24 inches in thickness and exhibit 0.1 percent, or greater, uranium with high ash content of about 35 percent and low-heating value.

The uranium content of these lignites varies widely between local deposits, and appears to be influenced by the permeability and thickness of the beds overlying the host rocks. Where permeable sandstone overlies the carbonaceous host rocks in thick beds, the uranium percentage is greater than where the same lignite or carbonaceous shale is overlain by clay or shale beds of lower permeability.

Lenticular uranium deposits in this region of the Williston Basin range from a few hundred pounds of ore up to 1,500 tons of ore. The blanket type of deposits have also been observed in the Little Missouri River escarpment region. A single deposit was described as follows: thickness, 1.78 feet; assay, 0.15 percent uranium oxide (U_3O_8); and overburden, ranging from 5 to 22 feet.

An article in Uranium Magazine (1958) reported 900,000 tons of proved uranium reserves for the western Dakotas with about half this total being located in the Little Missouri River escarpment.

The AEC chemically analyzed the samples from the subject region and found the following percentages: 0.18 percent uranium; 0.3 percent molybdenum; 0.09 percent phosphorous; and 0.01 percent vanadium.

The Little Badlands

Surveys of ground water in the Little Badlands (Location 2 of Figure 4) show fairly large percentages of uranium. However, even though geological factors appear favorable for commercial deposits of uranium, none were discovered. The general absence of carbonaceous material in the rocks directly underlying the Chadron and Brule Formations may largely explain the absence of significant deposits.

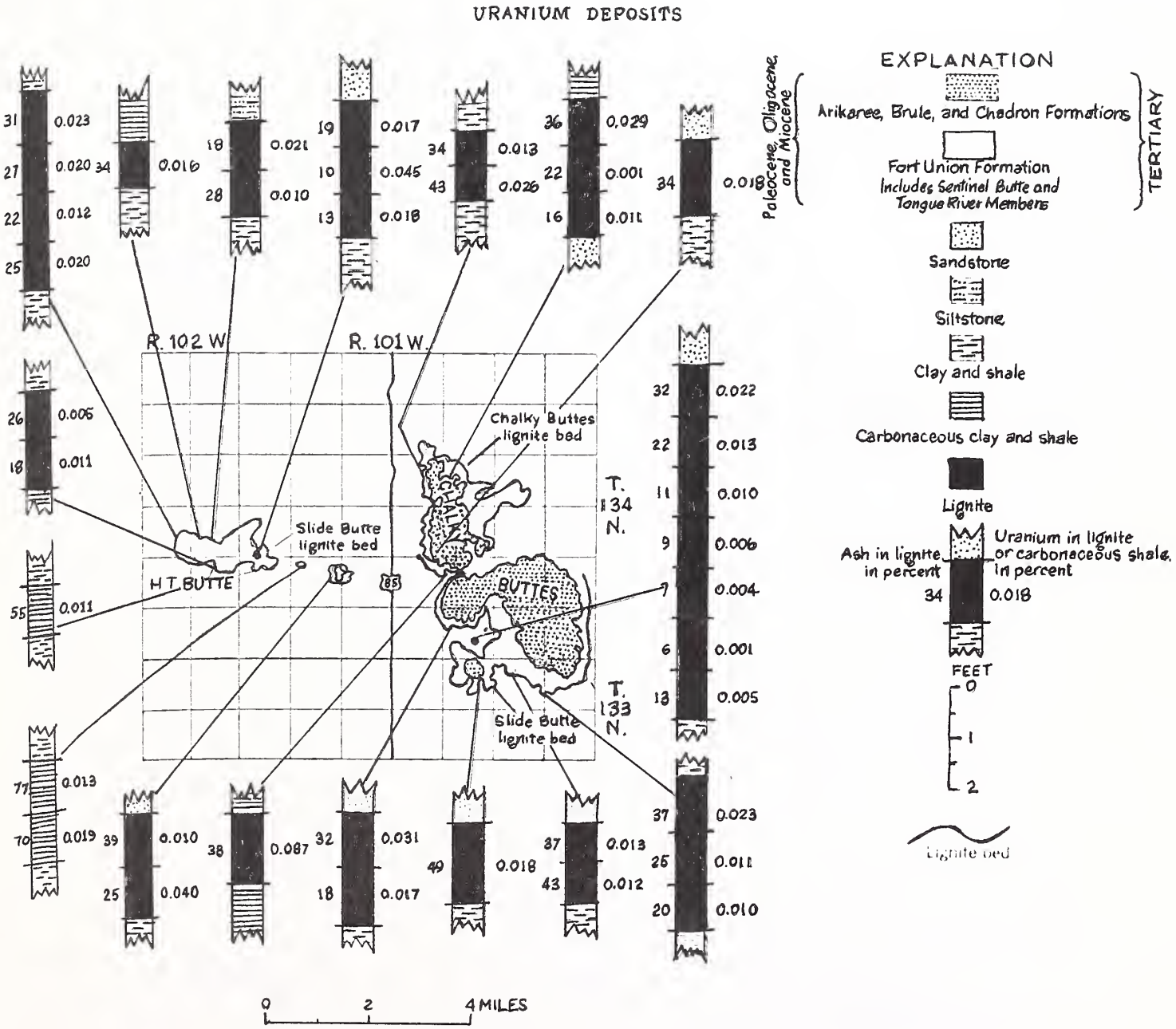


Figure 3. Uranium occurrences in Chalky Buttes area, Slope County, North Dakota. (From: U.S. Geological Survey)

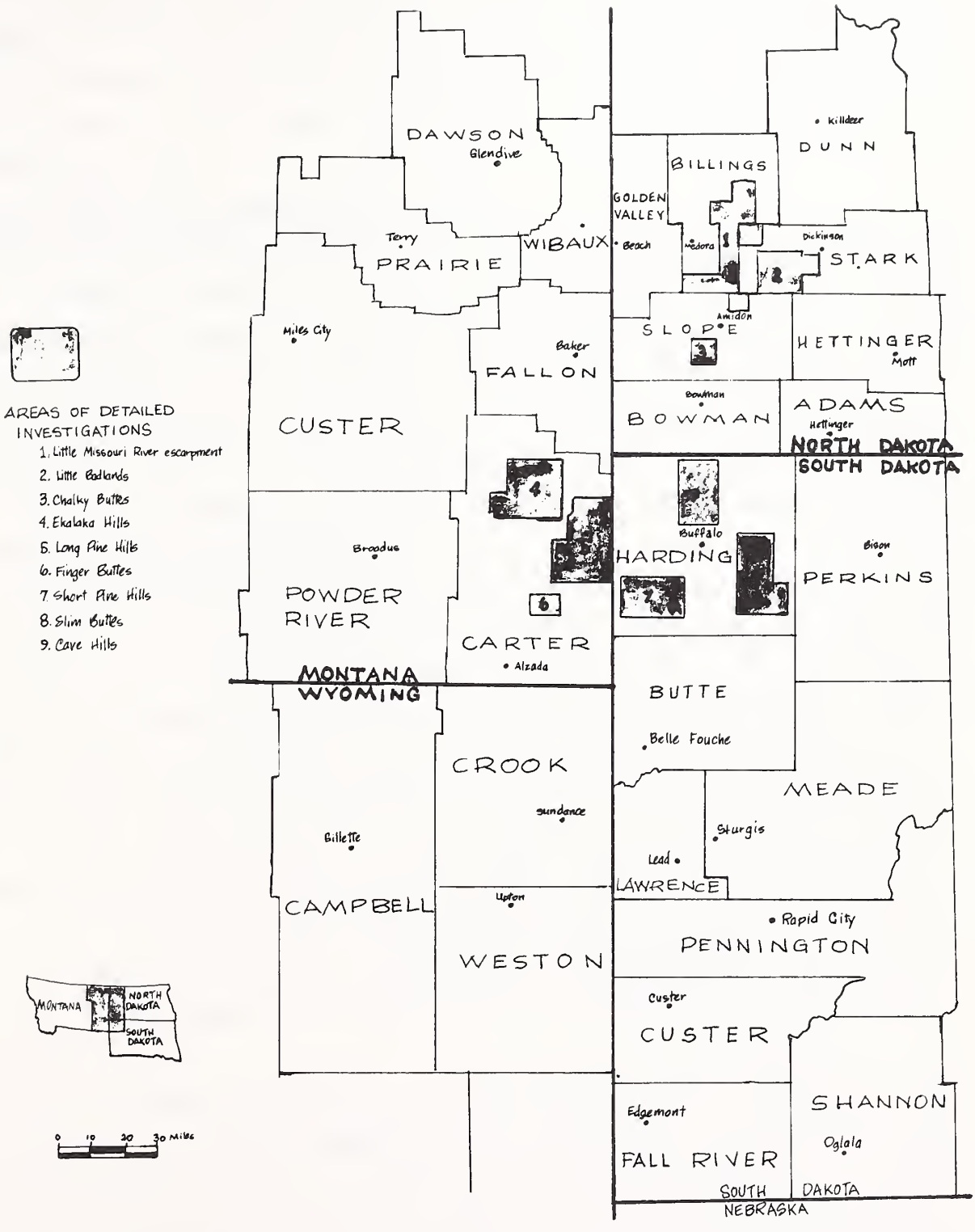


Figure 4. The numbered areas (1 to 9) have in the past been studied as to uranium deposits and are discussed herein. (From: U.S. Geological Survey, 1965)

Small deposits of uranium occur in the following two areas of the Little Badlands: (1) $NW\frac{1}{4}NW\frac{1}{4}$ Sec. 31, T. 139 N., R. 97 W. from which area a sample of lignite showed 6 percent ash and 0.09 percent uranium, and (2) $NE\frac{1}{4}NW\frac{1}{4}$ Sec. 28, T. 138 N., R. 98 W., where carnotite was discovered by X-ray analysis. The carnotite exists as a coating in the joint planes in massive beds of tuffaceous claystone in the upper layers of the Chadron Formation. (3)

Sampling of Water for Uranium Detection

At present (1978), efforts are under way in Montana (see NURE discussion herein) to determine uranium content of flowing waters. Similar analyses were also being conducted by U.S. Government agencies as far back as the 1950's and early 1960's. In the past, water samples from the Little Badlands and samples of water from the Chadron and Brule Formations were analyzed. Four samples from the Fort Union and Golden Valley Formation showed an average uranium content of 2 parts per billion.

Uranium Occurrences (Slim Buttes)

Low-grade deposits with 0.05 to 0.02 percent uranium, and with concentrations of 0.05 to 0.01 percent in the ash, are found extensively in Slim Buttes. At least 8 beds of lignite occur in the northern portion of the Buttes, ranging from 1 foot to over 14 feet in thickness. (3)

The central and northern areas of Slim Buttes were exploration drilled in 1951 and 1952 by the U.S. Bureau of Mines and the U.S. Geological Survey. Large reserves of low-grade uraniferous lignite were discovered. In the Mendenhall region alone, estimates indicate there are 49 million tons of lignite with 0.005 percent uranium in beds that average 5.4 feet in thickness. Exclusive of the Mendenhall area, the Slim Buttes are estimated to contain 340 million tons of lignite with 0.007 percent uranium.

In the southern Slim Buttes, investigators in 1955 analyzed water from springs and wells and suggested that the uranium content of ground water could possibly serve as an indicator of uranium deposits. Uranium discoveries in this region have shown that some of the high percentage uraniferous lignite deposits are located near springs that show 30 (ppb) parts per billion, or more of uranium.

An example of how ground water can be used in uranium prospecting is found in the Thybo deposit of uranophane-bearing sandstone which is

in the Fort Union Formation in the Reva Gap area of the northern Slim Buttes. The deposit was discovered in 1954 by a Geological Survey car using scintillation equipment; this exploration effort was prompted by the unusually high readings of uranium in the water of wells and springs. (3)

Short Pines

This area was originally known as the "Short Pine Hills." Samples of water from the tuffaceous rocks of the Chadron, Brule, and Arikaree Formations show an average uranium content of about 8 parts per billion. Samples from the Hell Creek in the Short Pines show an uranium content of around 4 parts per billion. A few samples showed an unusually high uranium content ranging from 20 to 598 parts per million. It is possible that these samples indicate significant deposits of uranium. (3)

Long Pines

Originally the "Long Pine Hills," the area is referred to herein as Long Pines, or Long Pines Forest. During early surveys (1924) the Long Pines rocks were mapped, mainly for land classification. In 1950, subsequent surveys noted weakly radioactive lignite in NE¼ Sec. 21, T. 3 S., R. 62 E.

Mapping of the middle and upper Tertiary tuffaceous rocks and collection of uranium indicator rocks were accomplished at Long Pines in 1955. (Figure 5)

Exposed rocks in the Long Pines region form an 800-foot strata of lignite-bearing strata of Late Cretaceous and Paleocene age overlain by 500 feet of tuffaceous strata of Tertiary age. The southwestern part of the Long Pines, near A-Bar-B Buttes exhibit tuffaceous rocks overlying marine Fox Hills Sandstone and Pierre Shale of Late Cretaceous age.

Most of the significant beds of lignite of the Long Pines occur in the Fort Union Formation with some thin lenticular beds in the underlying Hell Creek.

The Arikaree Formation ranges from 50 to 360 feet in thickness and exists as a cap-rock formation along hills of Long Pines, Sheep Mountains, and A-Bar-B Buttes. This formation is a chalky-gray sandstone with weak radioactive volcanic ash which exists in beds up to 12 feet thick.

Described as to structure, the hills in the Long Pines area follow

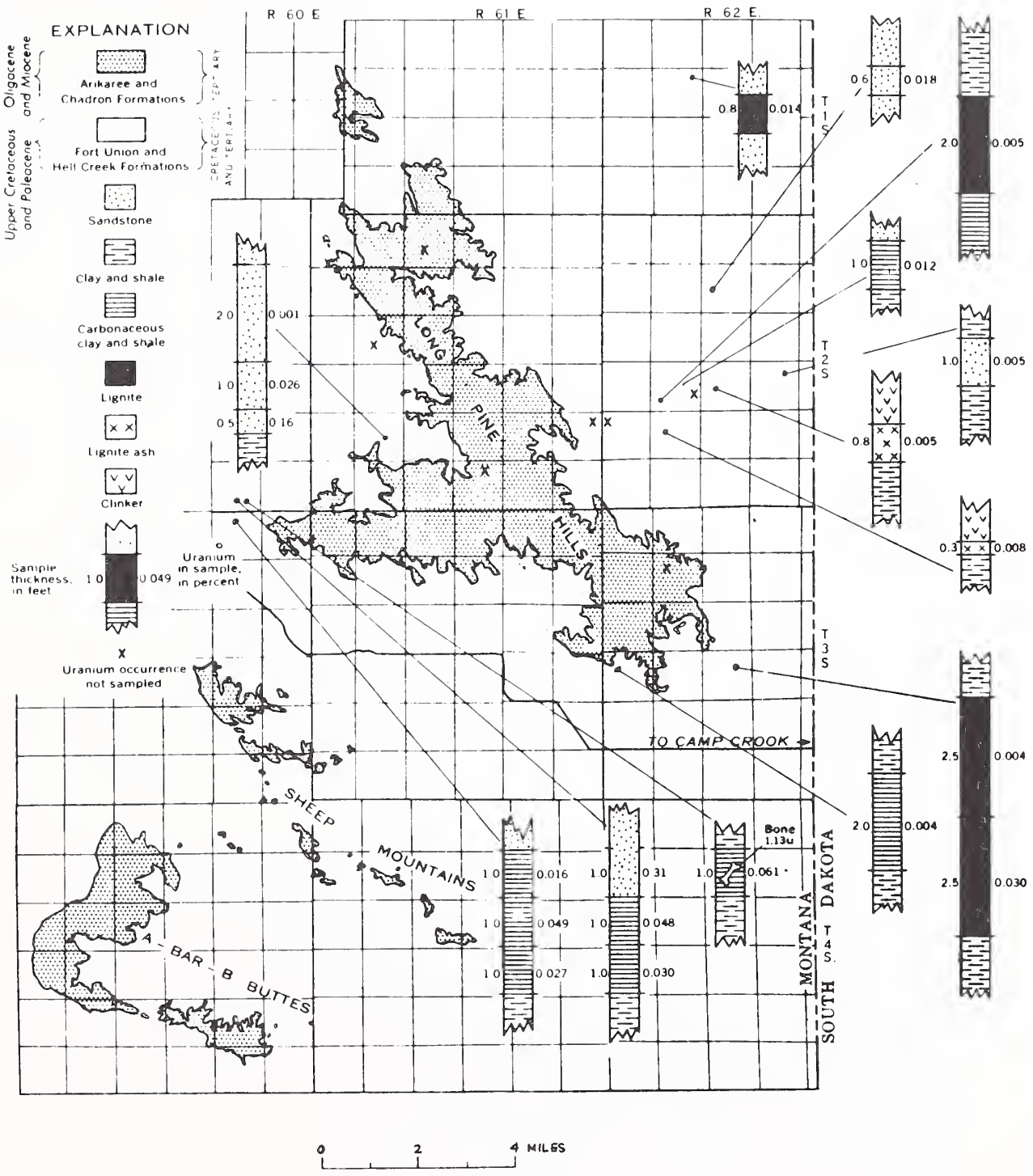


Figure 5. Uranium occurrences in the Long Pines area, Carter County, Montana (From: U.S. Geological Survey, 1965)

the northeast flank of the Black Hills. Lignite and carbonaceous shale beds in the Long Pines are only weakly radioactive and in most locales exhibit only small quantities of uranium. Of the 21 samples derived from 13 locations, scintillation and Geiger counter readings indicated uranium contents ranging from 0.003 to 0.061 percent. Fairly high uranium contents were discovered at only 2 of the 13 places sampled. These sampled areas are at the base of carbonaceous sandstone overlying thin lenticular beds of shale in the SW¼ SE¼ Sec. 35, T. 2 S., R. 60 E., and in the NW¼ SE¼ Sec. 20, T. 2 S., R. 61 E. Samples of sandstone at these locations showed uranium contents of 0.16 and 0.31 percent, respectively. Study of the yellow coatings on sand grains and fracture planes indicates deposits of carnotite and becquerelite.

Ekalaka Hills and Chalk Buttes

Totaling about 30 square miles of forested land in north-central Carter County, the Ekalaka Hills have in recent years experienced extensive uranium exploration activities. The Chalk Buttes are located about 4 miles to the southwest. (Figure 6)

Beds of radioactive lignite and carbonaceous shale occur in the Fort Union Formation (Paleocene) about 1,100 feet above the Pierre Shale. Rocks exhibiting uranium appear in the southwestern portion of T. 1 N., R. 59 E., and in the southeastern part of T. 1 N., R. 58 E. Lignite-bearing rocks dip about 70 feet per mile to the northeast. The radioactive carbonaceous beds are overlain by the Arikaree Formation in most locations. (3)

In the Ekalaka Hills, uraniferous lignite and carbonaceous shale range in thickness from 1.5 to 8 feet and exhibit from 0.001 to 0.034 percent uranium with an average uranium content of about 0.005 percent. Water analyzed from the Arikaree Formation shows only about 6 (ppb) parts per billion, which is significantly lower than water from this same Formation in other regions. It appears that the tuffaceous rocks in the Ekalaka area contain less uranium than do rocks elsewhere in the Williston Basin.

The uraniferous lignites of the Ekalaka Hills contain analcite and barite which contribute to the high ash content of the samples.

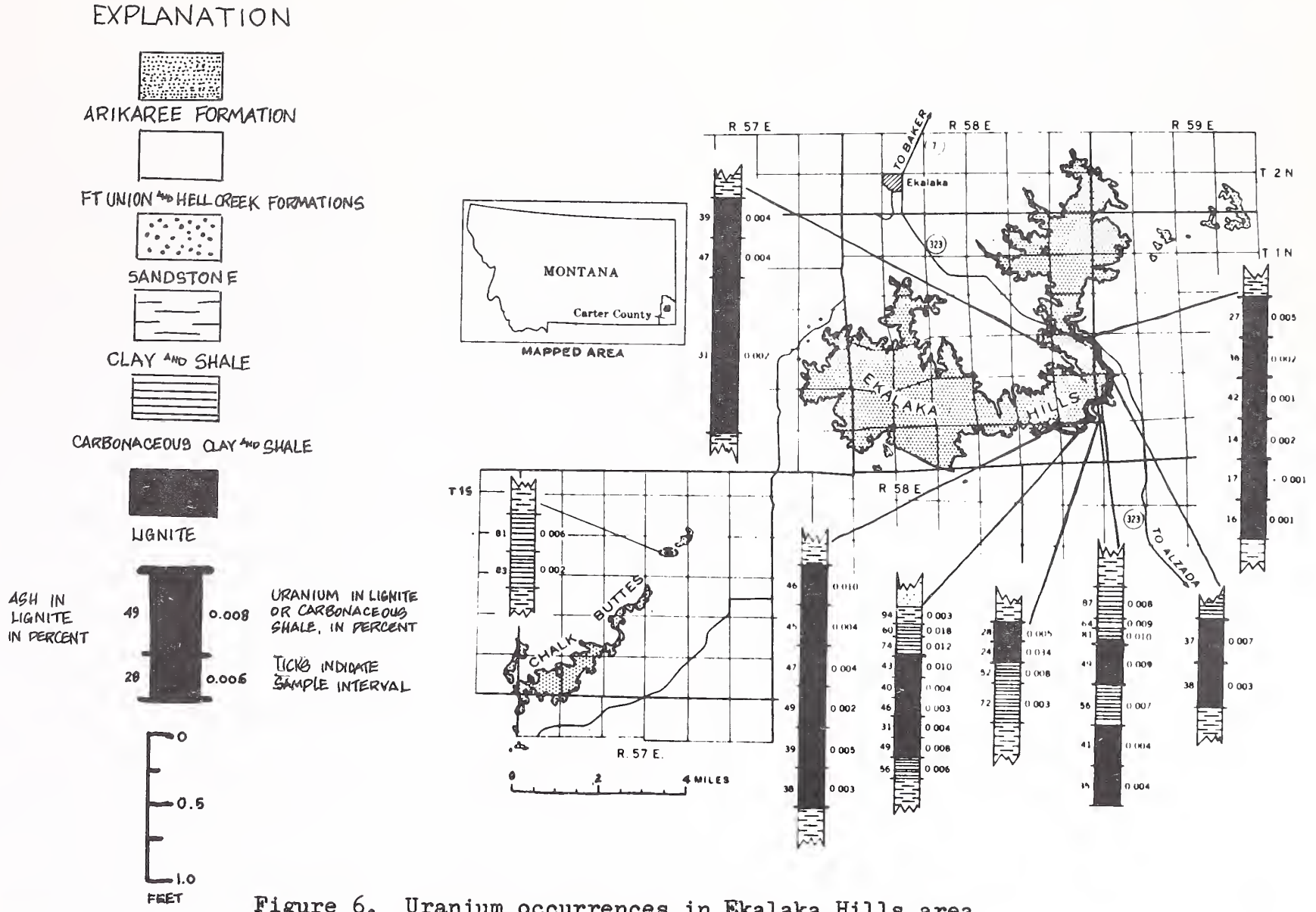


Figure 6. Uranium occurrences in Ekalaka Hills area, Carter County, Montana. (From: U.S. Geological Survey)

I. Analyses

Studies of rock samples from the general region of the uranium lands included chemical and semiquantitative spectrographic analysis on 288 rock samples and on fossil bone. The various rocks sampled included volcanic ash, tuffaceous sandstone, claystone, bentonite, and arkose. Purpose of the sampling was to determine the variation in composition and trace-metal content of a series of mildly radioactive tuffaceous rocks which probably are the source of uranium now concentrated by action of ground water in the underlying formations. (3)

Chemical analyses were made on 15 samples of fossil bone to determine uranium content. It was discovered that surfaces of the bone subject to permeability showed a higher uranium content than the surrounding rock. The bone samples showed from 0.003 to 0.79 percent uranium and enclosing rocks showed only 0.001 percent or less.

J. Summary of Williston Basin Uranium

Uraniferous lignite and carbonaceous shale are found in the Williston Basin and occur at many horizons throughout about 2,500 feet of deposits ranging from Late Cretaceous to Eocene in age. The uraniferous beds average 2 feet in thickness and exhibit about 0.008 to 0.2 percent uranium. Reserves of rock with what may be mineable percentages of uranium are estimated to total more than 1 million tons, and many are overlain by relatively thin overburden which would not discourage strip mining. (3)

Richer deposits of uranium extend on a north-south axis through Williston Basin. The best of the deposits occur in the North Cave Hills and Slim Buttes (Cedar Canyon area), Harding County, South Dakota and also along the Little Missouri River escarpment near Saddle Butte and Rocky Ridge in eastern Billings County and in northwestern Stark County, North Dakota.

In these areas of the Williston Basin, the richest and most extensive uranium deposits are overlain by massive and thick porous sandstone beds. The sandstone beds around 200 feet in thickness, have probably carried the mineralized solutions laterally for great distances. Downward and lateral movements of ground water appear to have leached uranium from tuffaceous materials in the Oligocene and Miocene rocks and subse-

quently redeposited it in carbonaceous rocks of the area. (3)

3. THE PEACEFUL ATOM

A. Natural Radiation

In 1896, Henri Becquerel found that uranium produced natural radioactivity very similar to X-rays which had been documented by Wilhelm Roentgen one year earlier. Following Becquerel's experiment it was determined that the atoms of heavy metals such as uranium or thorium are constantly, though very slowly, breaking down and giving off alpha rays and beta rays as well as X-rays.

Becquerel received a Nobel Prize in physics in 1903 for the discovery of radioactivity in uranium. Roentgen had in 1901 won the Nobel Prize in physics for discovering the X-ray.

B. Earth's Background Radiation

Most of the earth's background radiation consists of gamma rays or X-rays, which result mainly from the radioactive decay of unstable potassium, thorium, uranium, and other radioactive elements in the soil. These elements are found in minerals nearly everywhere. In some areas of the world's surface, such as Brazil or India, the background radiation actually exceeds the extremely low-level radioactive safety limits established by the U.S. Government. (4)

The atom is stable, but can be bombarded with atomic particles and its energy level raised, thus making the atom radioactive. As the atom disintegrates it gives off energy in the form of radiations and reaches a stable state; heat develops. The heat creates steam which is used to drive the turbines that produce electricity. In computing the net energy derived from uranium, all of the input energy (developing the ore, processing, enrichment, etc) must be subtracted from the gross output. Essentially, and finally, the application of nuclear energy must justify this input/output relationship. Nuclear energy in medicine and space applications is an excellent example of usage justifying the input of energy (i.e. the exploration, mining, processing, enrichment, transportation, etc). This usage tends to overshadow the tradeoffs inherent in concerns relating to safety, the environment, etc.

C. What About Radioactivity?

Nuclear power plants and nuclear operations are by no means the only producers of radioactive radiations. Natural background radiation in our daily lives and throughout the environment varies with geological types, time of year, altitude, latitude, and other factors. In addition, we receive cosmic radiation from the sun. Radioactivity exists in our soils, fertilizers, fossil fuels, and also within our own bodies. (4)

The allowable minimums of radioactivity for nuclear power plants are a great many times below background radiation. As pointed out by nuclear researchers, there is no place in the United States where the natural background radiation is not many times as great as the amount of exposure that will be added annually for the closest neighbor of any one of the nuclear power plants that must, of course, operate under strict Federal and State guidelines. There are currently about 64 nuclear power plants in our Nation. Researchers have pointed out that there is no sizeable community whose average radiation exposure is likely to increase more than 1 percent as a result of all the nuclear power plants that are planned for the foreseeable future. (4)

Conversely, there are other nuclear and medical researchers who continue to hold to and explore the view that all radioactive exposure, no matter how low-level, is accumulative and thus worthy of further study and concern.

When speaking of nuclear radiation, we are referring to "ionizing radiation" which is capable of converting ordinary atoms into electrically-charged particles or ions. Nature has always produced such radiation. Today's man produces and uses radiation in many areas of research, including medical diagnosis and treatment. Nuclear power plants also produce low level ionizing radiation and thus become areas of concern and targets for very strict controls and safety measures to guard both the in-plant workers and general public within the plant's scope of potential radiation hazard.

A further area of concern falls under the category of "reconcentration." Fish, plants, or small organisms can ingest certain elements (such as phosphorous) and build up higher concentrations than those existing in the environment around them. In the aquatic environment, further concentration may occur as one species preys upon another. Reconcentration,

as well as the accumulative effect of more than one nuclear reactor within a geographical area, are recognized and regulated as to amounts of allowable radionuclides permitted for each generating station. These concentrations, if allowed to develop, eventually would reach man and also would adversely affect humans in a variety of ways.

Typically, the amount of radioactivity escaping from a nuclear power plant is so small that differentiating it from the background radiation may be extremely difficult. (4)

D. Fusion Power

As one of the most environmentally attractive sources of potential energy known to man, fusion power would use a form of hydrogen, called deuterium as its primary fuel. Seawater contains enough of this material to provide fuel for fusion power over billions of years.

The most readily achievable fusion reaction occurs when deuterium fuses with tritium, a radioactive isotope of hydrogen; the nuclei of light elements collide at high velocity and fuse to form heavier nuclei and release energy.

It is difficult to determine exactly when fusion power may become commercially available. Current estimates from some sources (possibly optimistic ones) indicate that by year 2000 the first fusion power may be produced.

Fusion Power for the Distant Future

The theory, if not the execution, of fusion is quite readily accomplished. If a fully-ionized plasma of deuterons and tritons can be heated to 100 million degrees, and if it is sufficiently dense, and if it can be confined for a sufficient time span, the resulting collisions of the nuclei will fuse a sufficient number of these particles to release hundreds of times more energy than the process itself consumes.

Fusion, technically speaking, is a controlled thermonuclear reaction. It is the very same phenomena that causes an enormous release of energy from sun, stars, and the hydrogen bomb. The potential of fusion as a source of energy is tremendous. Advantages of using fusion include the following: (1) world oceans offer an infinite supply of deuterium; (2) there is no possibility of a major nuclear accident from the fusion process; (3) transporting, handling, and storing of radioactive material is minimized; (4) risk of radiation is very low; and (5) in case of a

sudden reactor shutdown, the handling of the heat load in a fusion reactor represents only a minor problem.

All of these attractive aspects of fusion have led some to suggest that we skip past development and perfection of the "breeder" and funnel our funds and forces directly into development of the fusion process. However, the technological feasibility of the fusion process has not yet been demonstrated even though more than 20 years have been spent upon its research in our Nation, in the Soviet Union, and elsewhere. (5)

Even with all of its advantages, fusion still could not suddenly solve all of our energy problems. However, if successfully commercialized, fusion does hold a promise of a future energy economy that could be self-sufficient indefinitely. Reactors for the fusion process will be costly and just as difficult and time-consuming to build as are our large fission reactors (the current LWR's).

Finally, all of our anticipated energy problems and needs present an extremely complicated mixture with no simple mono-technology solution. The answer to our energy problems also promises to be a complicated and possibly highly intricate mixture of techniques.

E. Alpha, Beta, and Gamma Rays

Alpha particles travel short distances in air and cannot penetrate a sheet of paper. Beta particles travel longer distances and can pass through paper, but not through light and low-density materials such as aluminum. Gamma rays are stopped only by thicker and more dense materials such as lead and steel. A sufficient amount of earth, of course, will stop all radiation. Underground shelters make use of this principle to protect humans both against blast and the radiation effects of atomic weapons. The attributes of these types of radiation also determine the means of packaging and transporting nuclear wastes.

Nuclear Radiation

Radioactive decay is the causative force behind radiation. The nucleus of certain atoms is unstable or unbalanced and part of the nucleus breaks away and releases some of the excess energy. Consequently, the nucleus changes into a completely different element. This process is called radioactive decay, and the energy given off is termed nuclear radiation. Within the earth, in rocks, and in our own bodies radioactive decay occurs constantly and is harmless if the process does not become

too concentrated.

Spent fuel from a nuclear reactor loses much of its own radioactivity before it is sent to the reprocessing plant. Usually, the spent fuel bundles are allowed to cool in a deep pool of water at the reactor site for three or four months prior to reprocessing; during this time about 99.9 percent of the radioactivity dissipates through the decay process. (6) (Figure 7)

The first commercial reprocessing plant for nuclear reactor fuel did not begin operation until 1966. Thus far, only a minimal amount of fuel has been reprocessed. Data from 1975 indicate that this plant was shut down pending Federal approval for modification and expansion. At this same date (1975) another plant was seeking a license for reprocessing operation, but actual shipments and operations are not expected to begin until the 1980's. By this 1980's date the Energy Research and Development Administration (ERDA) expects to have at least one of the two following alternatives available for handling this material: (1) storage in steel canisters in concrete vaults or steel casks held at or near the surface; (2) storage in geological formations, such as bedded salt.

Surface storage is designed for 100 years, with a retrievable capability built into the system. However, with either system the wastes can be removed for alternative storage or disposal elsewhere if such became desirable.

G. Plutonium

Known as possbily the most poisonous substance in today's world, plutonium has caused many "scare" headlines, but it also has specialized applications that cannot be fulfilled by any other power source.

Plutonium is formed during normal operation of a nuclear reactor and is the most important of the "heavy" radionuclides. The very existence of plutonium provides the need for reprocessing plants. During reactor operation, the uranium in the core decreases steadily, with some of it being changed into plutonium; however, a greater percentage of the uranium splits into fission products as the nuclear "binding energy" that holds the uranium nucleus together is released. Furthermore, the reactor's chain reaction is fed to a certain degree by the created plutonium which is also fissionable.

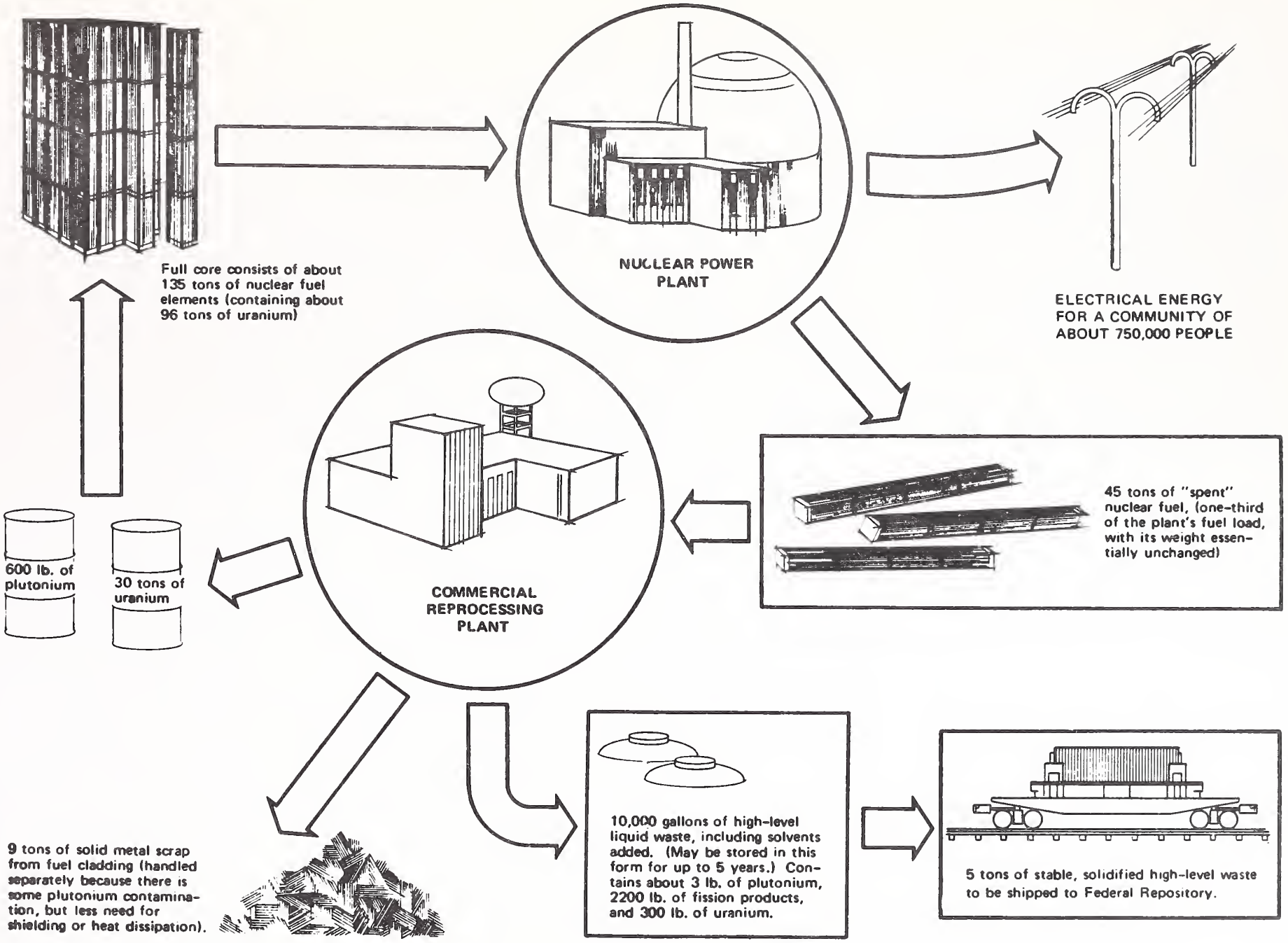

Full core consists of about 135 tons of nuclear fuel elements (containing about 96 tons of uranium)
NUCLEAR POWER PLANT
ELECTRICAL ENERGY FOR A COMMUNITY OF ABOUT 750,000 PEOPLE
45 tons of "spent" nuclear fuel, (one-third of the plant's fuel load, with its weight essentially unchanged)
COMMERCIAL REPROCESSING PLANT
600 lb. of plutonium
30 tons of uranium
9 tons of solid metal scrap from fuel cladding (handled separately because there is some plutonium contamination, but less need for shielding or heat dissipation).
10,000 gallons of high-level liquid waste, including solvents added. (May be stored in this form for up to 5 years.) Contains about 3 lb. of plutonium, 2200 lb. of fission products, and 300 lb. of uranium.
5 tons of stable, solidified high-level waste to be shipped to Federal Repository.

Figure 7. The fuel cycle associated with one year's operation of a typical 1000-electrical-megawatt nuclear power plant. (From: ERDA)

Every three or four years the reactor fuel elements are removed for reprocessing while the fuel elements still contain a portion of the original fissionable uranium plus a considerable amount of unfissioned plutonium, which is potentially valuable for use as fuel in other reactors. The reprocessing cycle is designed to pull out all of the valuable products, including plutonium, as is feasible within technological limits. Under present technical constraints all but a tiny fraction of the plutonium may be recovered for reuse. However, these tiny fractions of plutonium and similar materials that slip through the reprocessing cycle represent a serious disposal problem due to their extremely lengthy half-lives.

The alpha particles emitted by plutonium and alpha wastes produce very little heat during their decay cycles. Others of the fission products emit penetrating radiation that requires selective and substantial shielding.

Thus, plutonium's biological danger is based not on radiation hazard but upon physical entry into the lower animal or human system, which can occur through being inhaled or by some form of alimentary ingestion or absorption. Because of its non-radiation property, plutonium is successfully used in heart-assistance devices. In the future, such technology could possibly lead to a nuclear-powered mechanical heart. A greater heat-producer, plutonium-238, can be instrumental in generating a continuous, but small, electrical current and thus may power mechanical devices implanted directly into the lower animal or human body. The plutonium power-source is sealed in a suitable container and cannot be absorbed into body cells; thus, it is harmless to the recipient. During the Apollo moon mission, scientific instrument packages operated by plutonium-powered sources were left on the moon. (6)

If plutonium should be accidentally ingested or absorbed it would remain in the system just as would some chemical poison such as lead or mercury. Under these circumstances the radiations from plutonium would be extremely hazardous. Currently, ERDA nuclear data (6) states, "Tons of plutonium have been produced and handled by workers in the U.S. weapons program since 1945, and there has never been a single fatality from plutonium poisoning." The nuclear industry charts a careful course when handling and storing plutonium; i.e. plutonium (alpha wastes) is treated

as cautiously as other wastes from the more intense radioactive fission products and is isolated from the environment until decay is completed.

When isolating plutonium, the time span of its half-life demands special attention. The half-life of plutonium-239, which represents 60 to 70 percent of all plutonium in spent fuel, is about 24,000 years. This time span explains why so much concern has been given to burial of these products in salt beds and why disposal of wastes remain one of the important problems facing the nuclear industry.

The wastes from nuclear reactors are not important as to tonnage but as to inherent hazards. In fact, all of the fuel reprocessing considered for all commercial nuclear power plants (expected between 1977 and year 2000) will produce only about 30,000 tons to 60,000 tons of high-level waste when reduced to solid form.

H. Midterm Outlook for Domestic Energy

Uranium resources are shown in relation to other types of energy resources in Table 5.

Table 5. Estimated and Proved Energy Reserves 1/

Fuel	Definition	Original Units	BTU x 10^{15}	% of Total
Coal	In seams at least 42 inches thick with less than 1000 feet of overburden	200 x 10^9 tons	4200	86.0
Liquid Fuels	Proved reserves of oil and natural gas liquids	43.10^9 bbl	202	4.1
Natural Gas	Proved reserves of dry gas	267 x 10^{12} cu. ft.	275	5.6
Uranium	2/ Reasonably assured at less than $15/lb U_3O_8	520 x 10^3 tons	208	4.3
Total.....			4885	100.0

1/ Proved reserves are limited to materials in known deposits available for recovery under existing economic and technological conditions.

2/ Calculated at 400 x 10^9 BTU per ton U_3O_8.

I. Upgrading the Generation of Nuclear Power

The capacity for generating electricity from nuclear energy totaled about 26,000 (MW) megawatts in December 1974. Approximately 64 nuclear electrical generating plants capable of active operation existed in the United States as of 1976. The total power from these plants in 1974 equaled about 7.5 percent of the total electrical generating capacity of the United States; by 1977 this total had risen to 10 percent. (5)

Up through 1985 and perhaps longer, most of our nuclear-produced energy will derive from the light-water reactors (LWR's) which are the types of reactors currently in use. These reactors burn uranium enriched with the fissionable isotope uranium-235.

The LWR's have two significant weaknesses: (1) they discharge roughly 30 percent more heat to the environment than do modern coal-fired generating plants of equal capacity; (2) they are singularly inefficient and convert only about 1 to 2 percent of the uranium's potential energy into actual boiled heat for driving the steam turbines that generate electricity. (5)

This inefficiency problem will be reflected in the ever-broadening search for mining, milling, and enrichment of increasingly hard to locate and increasingly poorer-grade uranium ores. A move to increase the amount of electrical power from LWR's would have to deal with this obstacle, which is built into the basic technology of the LWR reactor. The expected growth of and dependence upon the LWR's means that increased amounts of yellowcake will be required: i.e. an increase of between 25,000 and 35,000 tons annually by 1980; increase of 70,000 to 120,000 tons annually by 1990; and increase of 100,000 to 200,000 tons annually by year 2000. (5)

Some consideration has been given to the mining of shales and granites for uranium in the United States. This, with few doubts, can be regarded as an extremely non-profitable solution. The uranium content of rocks is extremely low, on the order of 50 parts per million, or only about 2 percent of the uranium content of present ores. The production cost of such uranium would be in the $100 to $200 per pound category, and mining of such low-grade ore in rocks would present an extremely unfavorable energy development/environmental tradeoff. To produce an annual demand for 150,000 tons of yellowcake, in excess of 4 billion

tons of the so-called Chattanooga Shales would have to be mined every year; this is about seven times the volume of material currently disturbed by the Nation's entire coal industry. Such low-grade rock mining would require thousands of workers and hundreds of new uranium milling and processing plants. Economically and environmentally it would be unacceptable.

Dr. Peter Auer, Cornell Workshops on Energy Research and Development said, "The anticipated growth of the nuclear industry cannot be maintained with any credibility beyond the mid-1990's if it is to remain based on current generation converters (LWR's). In fact, we may observe in this connection that were we forced to utilize ore grades as low as 50 parts per million of U_3O_8 in present day converters (i.e. uranium reactors), the energy content per unit weight of rock would be comparable to coal. As a consequence, one of the attractions of nuclear energy -- minimal impact on land due to mining -- would be sacrificed."

It is suggested that to ease future demand upon yellowcake resources and upon enriched uranium fuel, the plutonium could be recycled as part of the LWR fuel charge. Similar to uranium-235, plutonium-239 is fissile, and it can release energy in a nuclear chain reaction. The normal reactor operation produces plutonium-239. This plutonium can be recovered during the reprocessing of reactor fuel elements. Future uranium mining, milling, and enrichment requirements could possibly be reduced by as much as 30 percent.

J. Thorium for Production of Energy

Two new reactor concepts explore the use of thorium and the fissile uranium-233 isotope in the reactor fuel cycle. These concepts include: The High Temperature Gas Reactor (HTGR); and the Light Water Breeder Reactor (LWBR).

Successful development of the thorium/uranium-233 fuel cycle would just about double quantities of low-cost ($10 per pound uranium -- under 1975 pricing constraints) fuel available for nuclear power generation. However, even with this advantage the low-cost uranium and thorium eventually would be depleted.

Thus, an additional breeder reactor, the Liquid Metal Fast Breeder Reactor (LMFBR), which generates more fuel than it consumes, is being researched and developed. It is estimated that this breeder reactor

(LMFBR) can be perfected to a point at which the original fuel charge of fissile fuel will be doubled in as little as 10 years, thereby creating fuel for additional breeder reactors and consequently decreasing the extent of uranium mining, milling, and enrichment, possibly to a negligible scale. (5)

Because the breeder (LMFBR) fuel cycle is 30 to 50 times more fuel-efficient than that of the current LWR's, nuclear energy production could become essentially free from impacts of rising fuel costs, thus assuring a reliable source of electricity far into the future.

The above scenario of unlimited electrical power will be moderated by future events and must be viewed in terms of the possible future constraints upon nuclear energy, such as competition from other energy sources, safety, and waste disposal problems as detailed elsewhere herein.

Nevertheless, the breeder, and finally fusion, are the logical progression if current research and development continues successfully.

K. How the "Breeder" Reactor Works

A brief overview and generalized account of how the breeder (LMFBR) operates is presented in the following paragraph.

> "Nuclear fuel consists of fissionable atoms whose nuclei can be broken apart (fissioned) by the impact of atomic particles called neutrons. Certain elements, called fertile materials can be made fissionable. The LMFBR would have a fuel core containing plutonium-239, a fissionable material, and uranium-238, a fertile material. The core would be surrounded by a blanket or uranium-238. In the blanket, fertile uranium-238 would be turned into fissionable plutonium-239 when the nuclei of the uranium-238 atoms absorbed the neutrons generated by the plutonium. Meanwhile the heat from the fissioning of the plutonium or uranium nuclei in the core would be used to produce steam for driving turbogenerators to produce electricity, and the plutonium-239 formed in the blanket could be used in the future to fuel other reactors. The breeder will produce about 5 pounds of fuel for every 4 pounds it consumes." (5)

The LMFBR has in our Nation been assigned a high priority of funding and research dedication. This priority has been awarded the LMFBR

projects because of the anticipated depletion of uranium fuel resources that are currently available at acceptable economic and environmental costs.

Estimates of future nuclear power capabilities have followed a downward trend, due to lengthening lead times for construction of nuclear plants and problems that utility companies are experiencing in the raising of capital for such plants. For example, in 1971 the Government anticipated 151,000 (MW) megawatts of nuclear generation capacity for the Nation by 1980. This estimate was lowered to 132,000 MW in 1972 and again reduced to 102,000 MW in 1974. (5)

There seems to be little question in the minds of many researchers and scientists that ultimately the breeder reactor (LMFBR) will be the basic answer to diminishing uranium resources and the uranium supply problem. Projections indicate that 700,000 to 950,000 tons of yellowcake will be required to fill LWR needs between 1973 and 1991. Furthermore, to stabilize the nuclear power industry in 1990, an 8-year forward reserve assurance of another 1 million tons of uranium is required.

4. MODERN TECHNIQUES OF URANIUM EXPLORATION

One mining engineer, when asked how his company located an uranium mine, replied, "If you're going to hunt elephants you go where the elephants roam." This reflects the fact that today a new uranium mine most often and typically may develop in the vicinity of already heavily-explored and perhaps partially-developed mines.

In the earlier stages of locating mineable uranium deposits, exploration activities include: aerial surveys; on-land geological studies; and finally drilling and testing to determine detailed percentage-content of the ore. The exploration phase may begin with assessment of areas ranging from 100 to 1,000 square miles which may be narrowed to areas of 10 to 100 square miles. Studies and other efforts to meet the necessary State and Federal environmental requirements may extend over a period of one or more years.

Development of an ore body that has been deemed worthy of mining includes drilling of more closely-spaced holes to determine the outline and thickness of the ore body as well as depth of location and percentage

of uranium content. Hydrologic characteristics of the ore deposit are determined as well as the characteristics of any involved ground water. Special studies of the aquifers are necessary to allow successful solution mining and to avoid damage to them and assist in planning for post-mining reclamation.

Drilling test holes in Montana is accomplished under existing State and Federal regulations; permits are issued and primarily regulated by the Montana Department of State Lands. The U.S. Forest Service regulates drilling activities within Long Pines and other locations of the Sioux Ranger District (Montana and South Dakota) and oversees associated activities.

Generally, modern exploration efforts include: aerial surveys; surface (on-land) surveys; geochemical surveys; drilling and sampling; use of electronic equipment in drill holes, etc. The NURE Program promises to add more data regarding location of uranium deposits.

A. The NURE Program

Currently under way in the Nation, and in Montana, the NURE (National Uranium Resource Evaluation) program under ERDA is aimed at surveying the unexplored areas for uranium. The NURE program, initiated in 1974, also is designed to develop new and improved geophysical and other technology; completion of the program and a final report is scheduled for 1981.

Additional steps to more adequately assess the Nation's uranium resources include the suggestion to investigate the tens of thousands of wells and holes drilled each year in the United States in search of oil, gas, water, mineral exploration, seismic study, geothermal exploration, etc. Under this plan these holes would be checked for gamma-ray emissions to determine presence of radioactive materials. In the normal course of business, oil companies frequently conduct gamma-ray logs to obtain needed data. Costs involved in completing the log to the surface would not be prohibitive and a means of protecting the company's ownership of the data could be developed. Such an effort could add essential data on uranium and thorium resources to our existing knowledge.

Main objective of NURE is the evaluation of the Nation's uranium resources and indentification of areas of interest for uranium exploration. Field operations include sampling of surface waters, ground waters, stream and lake sediments throughout the states of Montana, New Mexico,

Colorado, Alaska, and Wyoming. In Montana the average sampling density is one sample per ten square kilometers (four square miles). (7)

B. The Lone Prospector

The days of a lone prospector roaming the hills are not completely gone, just extremely diminished. Although many, or even most of the world's major deposits of uranium have been discovered, exploration, mostly by larger companies, continues to be both widespread and intensive on the Northern Plains. If today's individual uranium explorer should happen to locate a potentially-developable deposit he will most likely sell out early to a large company that can complete the exploration and development work and properly conduct assessment work. Uranium exploration and subsequent assessment work is expensive, mostly unpredictable, and played for extremely high stakes. The individual and small "wildcat" group are not always capable of operating at a level sufficient to compete economically with established companies. Essential environmental studies, obtaining of permits, and necessary development and reclamation work tend to limit uranium exploration and subsequent assessment obligations to the larger company with sufficient capital for such efforts. (Table 6)

Table 6. Uranium Exploration in the United States. (From: ERDA)

Land	1966-1975	AVERAGE/YEAR (10 Years)	1975
Acquired.....	30,820,000 acres	3,082,000	3,480,000 acres
Held 12/31/75.....	- -	- -	11,840,000 acres
Surface Drilling:			
Exploration.....	122,270,000 feet	12,227,000	15,690,000 feet
Development.....	44,850,000 feet	4,485,000	9,730,000 feet
Exploration &..... Development Reported Together	12,570,000 feet	- -	- -
Total....	179,690,000 feet	16,712,000	25,420,000 feet
Expenditures:			
Land Acquisition	$104,380,000	$10,438,000	$16,700,000

Land	1966-1975	AVERAGE/YEAR (10 Years)	1975
Surface Drilling Exploration	$211,340,000	$21,314,000	$51,920,000
Development	$58,400,000	5,840,000	21,890,000
Exploration & Development Reported Together	$13,700,000	- -	- -
Other Expenditures	$147,660,000	14,766,000	31,520,000
Total.....	$535,480,000	$52,358,000	1/ $122,030,000

1/ 1976 and 1977: ERDA figures indicate that exploration expenditures in 1976 will increase to $157 million. Estimates for 1977 show a total of $168 million for exploration.

During a local-cafe discussion with a former individual uranium prospector and oil man, his verbal assessment of the "uranium situation" was that the lone individual prospector is today operating at a great disadvantage because (in his opinion) the larger companies often "buy up or otherwise acquire and sit on mineral leases" rather than developing them. In essence, this view merely reflects the fact that the day of the one-man prospector has been greatly diminished by economic pressures and changing environmental and operational requirements.

C. Exploration in the Southeastern Corner of Montana

Uranium exploration in Carter County has been accomplished in recent years from depths ranging from 400 feet to 1,300 feet by several companies, including: Kerr McGee; Frontier Resources, Inc.; Mobil Oil Corporation; Pioneer Nuclear, Inc.; Felmont Oil Corporation; Montana Nuclear Corporation, and Exxon Oil Company. Focal points for much of the exploration drilling has been in the following areas: upon or adjacent to Long Pines: northeast of Long Pines in Carter County (and Fallon County); and in the Alzada area.

Exploration drilling efforts at Long Pines in Carter County have sampled depths ranging from 400 feet to 1,300 feet. Several major companies have been active in the southeastern corner of Montana in recent years. (Map B, fold-out at back of report)

Over the past 12 years the percentage of "shallow" exploration drilling in the Nation has decreased and the "deep" drilling has increased.

Drilling at depths less than 400 feet has decreased from 80 percent of total drilling accomplished to less than 30 percent. Uranium exploration drilling to depths greater than 2,000 feet has increased from less than 3 percent of total drilling to about 15 percent.

Mobil Oil Corporation in 1973 staked 1,165 mining claims covering approximately 23,000 acres of public lands within the Long Pines Forest, which has a total of 69,997 gross acres or 66,545 net National Forest acres. Recent data indicate Mobil now holds mining claims on 36,620 acres of the Long Pines Forest (8).

In 1973, Mobil drilled 199 test holes ranging to depths from 200 to 1,200 feet, and approximately 4 3/4 inches in diameter (9).

After much early exploration, it now appears that Long Pines uranium generally lies excessively deep for economical open-pit mining. Furthermore, the U.S. Forest Service states that they will recommend to the Bureau of Land Management (i.e. the agency that issues leases) that no applications be approved for surface (strip) mining. Additionally, if this recommendation against such mining was ignored, then the mine company would have to prepare and submit a reclamation plan that was acceptable to the U.S. Forest Service.

In the Long Pines, exploratory drilling follows the commonly-used method of drilling lines of holes ("fences" as they are called) to determine the boundaries, thickness, percentage ore of the deposits, etc. Some of these lines of holes extend for distances of one mile or more. (Figure 8)

In current practice at Long Pines the drill holes are on 100-foot centers. Mining companies generally have found that this spacing sometimes does not gather all needed data; thus, additional exploration and developmental drilling may be accomplished half-way between the original holes on 50-foot centers, or even closer in some locations. Relatively few holes are required for exploration drilling. However, prior to an actual solution mining operation as many as 2000 developmental test holes may be drilled in specific areas of the ore deposits. (10)

Other than Mobil Oil Corporation, one other major company has been operating near but not within Long Pines; this latter company is Felmont Oil Company, which may still control extensive uranium lease holdings outside and east of the Long Pines. Felmont also may still own some

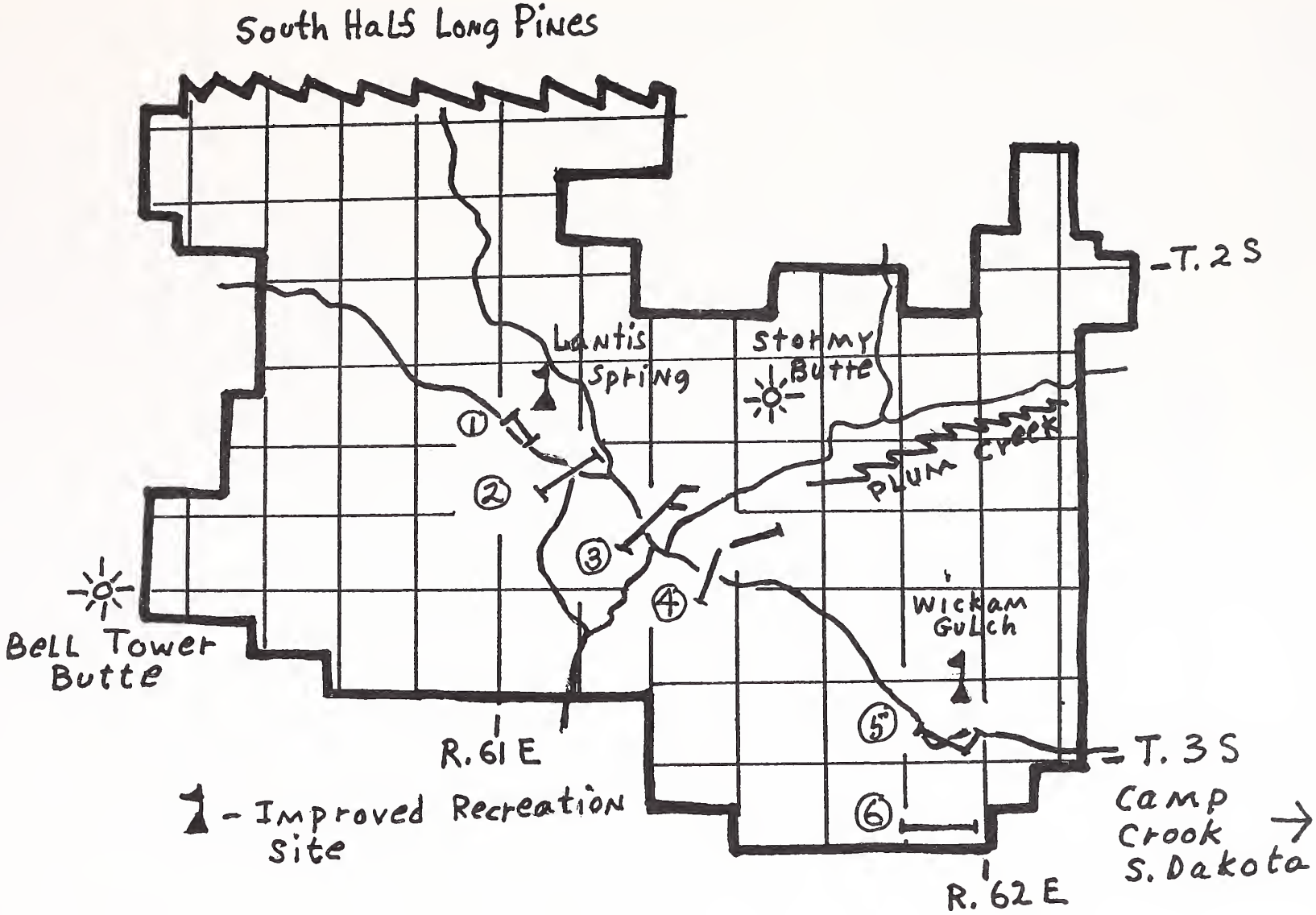


Figure 8. Approximate lines of drill holes (1 through 6) that were drilled by Mobil Oil Corporation on the Long Pines during July 1977.

mineral claims that extend into the northeastern corner of Long Pines. Felmont originally concentrated their exploratory efforts on the relatively shallower geological formations located east of Long Pines.

5. AUTHORIZED ACTIVITIES AND EXPLORATION ON PUBLIC LANDS

There will be no in-depth attempt here to interpret the 1872 Mining Law or to judge its merits. This report will portray available and selected insights into the 1872 Law and some of its effects upon public lands. Viewpoints of certain of the involved personnel and a condensed description of the Law itself (Appendix B) will be offered. In-depth interpretations of the 1872 Law and topics such as the need for up-dating and modernization are beyond the scope and intent of this report.

A. Exploration for Minerals on Public Lands

At the heart of the 1872 Mining Law (fully applicable in 1978) is the primary intent which generally states that all valuable mineral deposits in lands belonging to the United States shall be free and open to exploration and purchase. The primary intent of the 1872 Law is to implement the production (i.e. exploitation) of minerals on public lands.

Under provisions of the 1872 Law the western United States and it's public lands containing the large deposits of uranium,and a developing area for solution mining on the southern Texas coast will provide the primary supplies of uranium (Figure 9). In either the near or not-too-distant future, new areas of commercial uranium production may develop in southern Montana, northern Wyoming, and western South Dakota.

B. Management Provisions of U.S. Forest Service

Under the U.S. Forest Service current Management Plan for the Sioux Ranger District (i.e. National Forest lands of southeastern Montana and western South Dakota), such activities as deep mineral recovery,exploration by drilling, industrial sites, off-road vehicle use, power and telephone lines, roads, shallow excavation, small impoundments, temporary access roads, timber harvest, and underground utilities and pipelines are generally allowable within the restriction limits of the applicable mitigation requirements, except that hardwood draws, steep ponderosa areas, and rimrock areas are reserved against such usages. Activites and uses such as pit or surface (strip) mining and overhead high-voltage

Figure 9. Location of known uranium deposits in the western United States. (Note: This is a representative sketch showing approximate uranium deposits. After: Wyoming Mineral Corporation)

power-lines are disallowed in all areas of the Sioux Ranger District. (Long Pines Forest is within the Sioux Ranger District.) (11)

Areas of special value such as the Castles (600 acres); Capitol Rock (240 acres); and Wickham Gulch Camp (80 acres) are reserved against exploration drilling or similar commercial activities. Other Sioux Planning Unit areas managed only for recreation include Reva Gap (120 acres); Picnic Springs (160 acres); McNab Pond (90 acres); Lantis Spring (80 acres); Ekalaka Park (50 acres); Camp Needmore (250 acres). (Figure 10)

Under the Multiple-use Management Plan which strives for a balance between resources use and the maintaining of minimal changes in existing environmental values, the Forest Service emphasizes continued production of livestock, wildlife, and timber. The Plan provides for a moderate increase in development of energy-related resources such as oil, gas, and uranium within the constraints of proper land management.

The only specific industrial sites developed thus far in Long Pines include the following, which occupy less than five acres each: two radio transmitter sites located at Ekalaka Hills and Long Pines respectively; one oil-and-gas battery site in the North Cave Hills.

In future years, application for a special use permit for an uranium recovery plant on the Custer National Forest could occur if elements of the uranium "formula" (i.e. overburden-to-ore ratios; percent of uranium; market demand; and technological improvements in recovery methods) should combine to allow a profitable mining actvity. Applications for oil-and-gas-battery sites also could increase. The number of mineral claims staked on the entire Sioux Ranger District total approximately 2,240 with a total of 44,800 acres claimed. (11)

One oil well was initiated on the North Cave Hills area (South Dakota) in 1972 and produces about 42,000 barrels per year. Two newer oil wells on private land in the region produce about ten times as much oil as the North Cave Hills well. It is possible that this high production output may attract renewed oil activity in the Cave Hills and Slim Buttes region or Harding County, South Dakota.

C. Will Uranium Activity Increase on Public Lands of the Northern Plains?

A recent news article states, "The Club of Rome which comprises 100 eminent international scholars and scientists expects a commitment

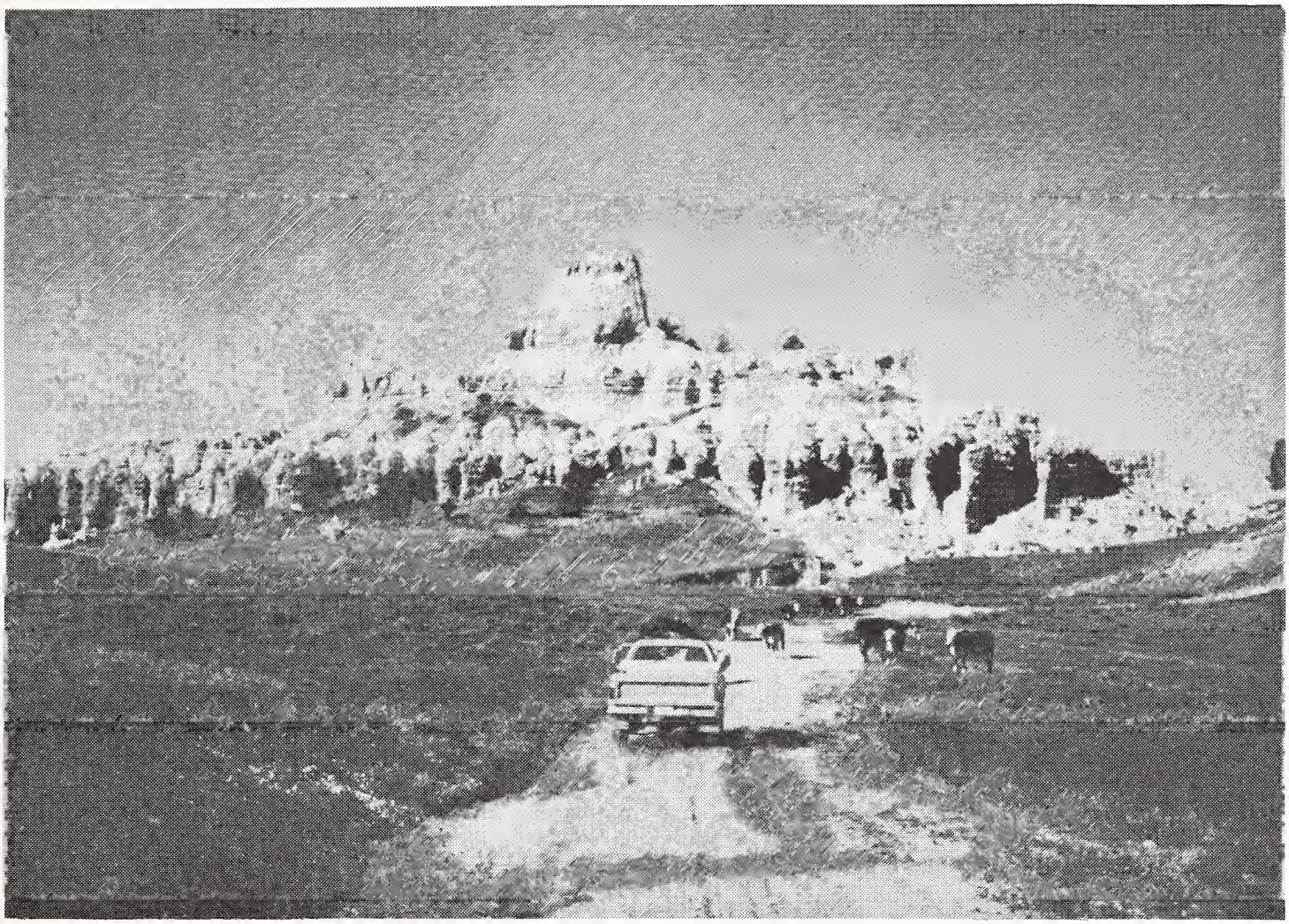


Figure 10. Capitol Rock and the surrounding 240 acres are reserved against development activities. The mineral claims held within this scenic area by a private company were voluntarily relinquished upon Forest Service request. (Photos, unless otherwise indicated, are by the author.)

to energy conservation in the United States (setting an example) to have a wide impact on fuel use in other countries, particularly in Europe, where overcrowding and dwindling natural resources pose an even greater problem. In their latest report the Club projects a dramatic drop in solar energy production costs, as investment in it increases. They predict a sharp escalation in the price of producing nuclear energy." (12)

Sharp increases in the cost of nuclear energy production and shortages of uranium may result in increased uranium activity on the Northern Plains as well as throughout uranium areas of the United States and the world.

6. SOUTHEASTERN MONTANA AND ADJACENT-STATES URANIUM DEPOSITS

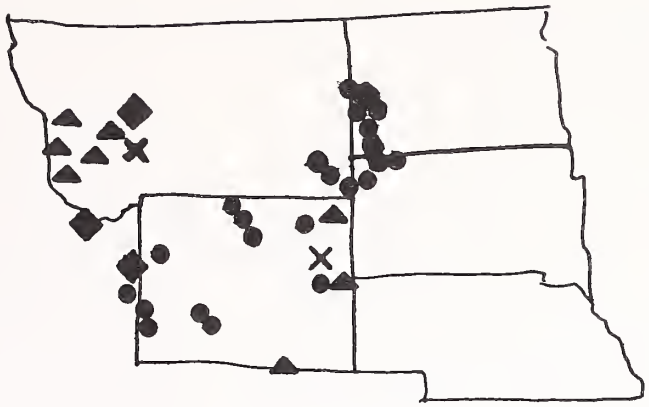
A. Uraniferous Lignites

Uraniferous lignites with varying uranium content occur in widely-separated portions of the United States. Highest level of uranium content as based on available data, occurs in the lignites of Montana, North Dakota, South Dakota, Wyoming and in the high-ash lignites of Nevada. Lignite ash contains a much greater uranium content than the black shales.

Deposits of these uraniferous lignites are more or less common to large areas in extreme eastern Montana and in adjacent states. (Figure 11) The uranium content generally is comparable to that of the black shales with uranium content of only a few thousands up to a little more than 0.01 percent.

In the 1960's the lignites were mined and processed for uranium under the Atomic Energy Commission uranium-recovery program. A plant (now non-operative) was constructed near Belfield, North Dakota to obtain uranium by burning the lignite, thus non-productively destroying the value of the coal.

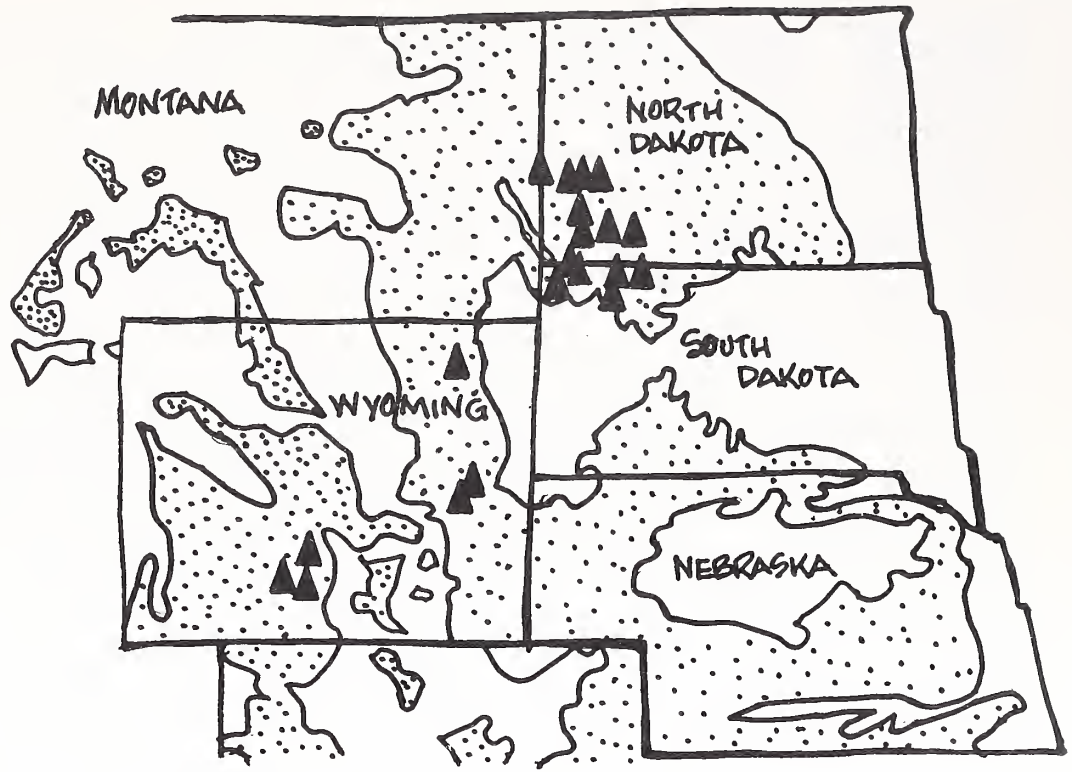
Under present market and technological conditions, neither the value of the Montana lignites as coal nor their sole value for the uranium content makes them economically mineable. No successful method has been developed for productively obtaining both the coal and uranium values. Furthermore, the above described AEC processing of the relatively rich lignites was less productive than was desirable at that point in time and the operation was discontinued. Some of these uranium mining



URANIFEROUS DEPOSITS

EXCLUSIVE OF PEGMATITES AND BLACK SHALES

- PITCHBLENDE
- VEIN TYPE DEPOSITS
- DEPOSITS WITH STRATIGRAPHIC CONTROL (SEDIMENTARY TYPE)
- DEPOSITS IN PHOSPHATE



URANIFEROUS COALS

- TERTIARY SEDIMENTARY ROCKS
- URANIFEROUS LIGNITE

Figure 11. Uranium deposits of the Northern Plains (After: U.S. Geological Survey, 1952).

efforts, generally in North Dakota and South Dakota, were price-supported by the Federal Government. When subsidy support ended, the private mine companies stopped their operations.

Percent of uranium content, total amount of ore-grade material available, and market receptivity determines when and where uranium mining will occur. Data on the exact percent content of the uranium ore being exploration drilled in Long Pines and in the Alzada region are not available; this knowledge is protected as privileged information by the private companies that own the mineral claims.

The uraniferous lignite beds occur generally throughout the subject region (i.e. the uranium lands) and exist in thicknesses ranging from one to nine feet. These lignite deposits have low BTU values and high ash content and offer amounts of lignite that are equal to adjacent coal fields located to the north and west. At present, these southeastern lignites have little commercial value other than the uranium content which will increase in value if market trends continue on their present upward course in the United States and world markets. Technological advances resulting in new and perhaps more urgent uses for nuclear energy and routine industrial-domestic needs could dramatically upgrade the value of these uraniferous lignites.

In the general region of the southwestern portion of Williston Basin, uranium is present in carbonaceous shale and lignite at various levels throughout 2,500 feet of the Upper Cretaceous and Lower Tertiary. These deposits of uranium are scattered from Harding and Perkins Counties in northwestern South Dakota to the western portion of Dunn County in southwestern North Dakota. Carbonaceous host rocks with the relatively high percentages of uranium show high ash content (35 to 40 percent) and low-heating values; these formations containing uranium range in thickness from 6 to 24 inches and on up to 21 feet thickness in some locations. (3)

By today's standards, with lower-grade deposits becoming more valuable, deposits even approaching a content of 0.1 percent uranium, if in sufficient quantity, are definitely considered for further exploration and possible exploitation. Deposits of uraniferous lignite and carbonaceous shale with higher than 0.1 percent uranium reportedly exist in the North Cave Hills and the Slim Buttes region of Harding County, South

Dakota and in the Little Missouri River escarpment in eastern Billings County and northwestern Stark County, North Dakota. Throughout these described regions, deposits of varying percentages are generally estimated to contain 150,000 tons of uranium-bearing ore-grade material, some of which may be extensive enough to offer commercial value in the future. In certain Cave Hills and Little Missouri River escarpment areas the uranium deposits lie beneath relatively thin overburden which could invite efforts at strip-mining at some future date (3).

B. Extraction of Uranium

Forest Service reports indicate that if extraction of uranium from the medium-grade to low-grade uraniferous lignites becomes feasible (due to market trends; improved technology; federal subsidy; etc) there is a potential for uranium mining of such deposits on some areas of the Custer National Forest.

Although the western United States contains extensive deposits of coal and carbonaceous (i.e. containing material such as leaves, twigs, branches, etc) shales with traces of uranium, under present market trends and technological capabilities they may be disregarded as current sources of recoverable uranium. The Fort Union formation in eastern Montana and North and South Dakota is the best known and most probable source of uranium from coals if such a recovery operation ever becomes feasible. A select few of the ore-grade lignites may contain up to as high as 5.0 percent uranium, (U_3O_8), but most of the ore is far below this very high percentage and may not average more than about 0.01 percent uranium. Characterized by thin ore beds, the uraniferous lignites may normally be overlain by 100 to 200 feet of barren rocks. In some cases where this material has been mined, strip-mining operations often included the removal of as much as 100 feet of overburden to mine a one- or two-foot-thick bed of ore. Difficulty is further offered by the softness of the ore which has a tendency to mix with or become diluted by waste materials. (Sandstone and various roll-front deposits also may exhibit this same problem.) Finally, as mentioned elsewhere, there may be no currently acceptable and economically-feasible method yet developed for treating the uraniferous lignite ore. (11) However, a newspaper account dated April 25, 1957 does report that the Atomic Energy Commission was successful in extracting uranium from lignite in its pilot plant at Grand Junction,

Colorado. Recoveries were stated as being good, but further work was considered necessary to reduce the cost and increase the economic feasibility of the process. (2)

Although the current commercial value is unknown, uranium has been detected in carbonaceous beds of the Arikaree and White River formations by the U.S. Geological Survey instrument reconnaissance. Radioactive beds have been reported atop the Ekalaka Hills and within the Long Pines area. Also, other radioactive deposits may exist east of Ridgway, near Arp, and near the head of Blacktail Creek. According to Soil Conservation Service documentation, a deposit of uraniferous lignite (a strongly radioactive seam) has been described somewhere in the area of Long Pines. Numerous other lignite outcrops with unknown commercial values exist in Carter County; however, none of these described radioactive beds are judged to contain commercially-feasible ore under present market and technological constraints. (13)

C. Recent Uranium Developments in Western South Dakota

The apparent swiftness with which an uranium mining and processing complex can be planned for regions that have seen either relatively low-key or no uranium activity over the past 10 years is reflected in the current activities in western South Dakota near Edgemont (adjacent to the South Dakota/Wyoming line) and generally in and around the region of the Black Hills. At least two major companies have efforts under way to open uranium mines and processing mills in this region, as early as 1978.

At present, the Tennessee Valley Authority (TVA) plans to start active mining in South Dakota in the early 1980's. According to company spokesmen they expect to be extracting a multi-million pound reserve of uranium with an annual production of around a few hundred thousand pounds for eventual use in their reactors in Alabama and Tennessee. The TVA requirements by the early 1980's predictably are estimated at 2 million to 8 million pounds of uranium concentrate per year with these amounts coming from TVA's own mining operations. (14)

Union Carbide is also active in this region of South Dakota and appears to be even closer to active uranium mining. Union Carbide may be planning to submit a development plan, involving the Black Hills National Forest, to the U.S. Forest Service. Furthermore, Union Carbide

may be scheduled to begin removal of overburden by 1978. Also Union Carbide is considering an uranium milling operation in connection with the discussed mining operation. The proposed mine might be of the open-pit type that would use leaching solution to extract the uranium. It is estimated that Union Carbide has claims and leases on over 32,000 acres in this general region of South Dakota (i.e. Edgemont/Black Hills region). (14)

Additional companies exploring the specific subject region of South Dakota for uranium include Mobil Oil Corporation, which may own uranium and coal prospecting permits totaling over 13,000 acres. Mobil may have thus far drilled around 4000 feet of uranium-exploration holes. (14) Recent information from an additional source (15) indicates that several companies have obtained uranium and coal prospecting permits as shown in Table 7.

Table 7. Uranium and Coal Prospecting Permits in Western South Dakota

Company	Location	Acres
Union Carbide	Butte, Harding and Perkins Counties	299,170
Mobil Oil Corporation	Harding County	13,154
Power Resources Corporation	Harding and Perkins Counties	262,410
Wyoming Mineral Corporation	Perkins County	160

Other companies involved in uranium activites in this region include Endak and Nokota Company. North and South Dakota may experience a continued rise in such activity and similar upswings in uranium activity may appear in Montana's future.

7. EXPLORATION AND MINING

A. Uranium Exploration Within Long Pines

Recent exploration drilling operations by Mobil Oil Corporation within Long Pines were completed July 1977. Observations during April and October, 1977 indicated that prior reclamation efforts on previous drilling sites dating from 1973 to 1976 were successful. Personnel from the Ekalaka area were seasonally hired by Mobil to dig cuttings-disposal pits, haul drill cuttings to the pits, and reseed and reclaim the drilling and pit sites by replacing reserved top soil and sowing native grass species.

No above-surface negative effects were observed. The temporary routes into some areas formerly inaccessible to motorized vehicles have now been closed. The Forest Service Management Plan limits creation of new roads.

Exploration uranium drilling efforts in the Long Pines and in several other areas of Carter County are aimed at the roll-front uranium deposits. These deposits developed in the sandstone formations; uranium carried in ground water precipitated from solution and coated the grains of sand. The extraction techniques of solution mining are designed to dissolve this precipitated uranium and separate it from the sandstone. In the Long Pines such roll-front formations, in addition to lignite deposits, represent the primary uranium resources.

Data on uranium percentages, exact ore formations, and prevalent methods of sampling and testing are usually lacking. These exploration data are guarded as proprietary information by the involved companies. Although data developed by Federal agencies is available to the public, such agencies do not enter into extensive drilling and assessment projects to the extent that is routinely accomplished by private companies.

Uranium prospecting, leasing, and exploration activities are somewhat reminiscent of early-day gold and silver exploration; an element of secrecy is readily detectable. Presumably this is at least to some degree based on practical necessity in that some modern version of "claim jumping" (claiming areas already filed upon by another party) or "paper-hanging" (the staking of claims to property actively under exploration by a rival company) can occur even in modern uranium operations.

Existing regulatory provisions administered by the Forest Service include concrete plugs for a continuous distance of 50 feet above and 50 feet below any drilled major water-bearing formations. This protection is designed to avoid post-drilling impacts which could cause interconnection and contamination of ground water in critical locations. Thus far, however, exploration drilling in the Long Pines has not intercepted the major water-bearing formations that hydrological data describes as existing in this region. A few active wells and developed springs, but very sparse water, exist within the Long Pines Forest. (Map C)

The lines of exploration holes drilled by Mobil Oil Corporation on 100-foot centers in the Long Pines are in some cases the extension of prior drilling programs. Some drilling lines intersect the primitive-style dirt roads and in such locations the test holes may be drilled through the road surface. (Figure 8) In these specific locations, company crews fill the holes with bentonite and use concrete plugs up to within about 30 inches of the road surface. This avoids the possibility of having a caved hole or concrete plug interfere with future work on the road. The upper 30 inches or so is filled with material similar to the original roadway.

When moving haul trucks or drilling equipment over Long Pines roads, pilot cars are used to ensure safety. Roads are narrow and visibility is limited on many curves and hills. Some roads have been slightly improved (graveled) at the expense of the involved private company for use by their trucks and drilling equipment. If roads are blocked by drilling equipment, company personnel guard the intersection and route traffic onto alternate roads leading to the desired destination.

Visible post-drilling evidence indicates that Mobil Oil Corporation, the only company drilling for uranium within the Long Pines, observes Forest Service recommendations and takes considerable precautions to avoid unnecessary damage to or opening up of tree cover when preparing a new route into roadless areas. (There are no "Roadless Areas" or "Wilderness Areas" as specifically defined under Forest Service management terminology, but there are some relatively large wooded tracts through which no access is available to motorized vehicles.) Larger trees and patches of thick growth are avoided by the drilling crew whenever possible; the natural avenues between the trees or the abandoned trails and

logging roads are used to the greatest possible extent. Trees that cannot be avoided are cut level with the earth's surface; poles and logs may be rolled across the route to serve as an effective but temporary closure. (Figure 12)

Timber sales amounting to an average of 576 thousand board feet are routinely scheduled by the U.S. Forest Service each year, primarily on the Long Pines Forest (2); thus the area can not be considered as preserved wildland. This commercial usage and the additional prescription thinning, to some degree at least, reduces the effect of the relatively insignificant tree cutting done thus far in association with exploration drilling. This timber supplies a sawmill located at Camp Crook, South Dakota.

When conducted by an agency or company that observes acceptable and reasonable methods, exploration drilling probably does little above-surface environmental damage. However, the National Forest portion of Long Pines is itself a relatively small woodland (basically 66,000 acres, net). It is an isolated grouping of hills, scenic bluffs, and ridges in a botanically-monotonous sea of flat-to-rolling grasslands and thus offers a high quality and unique scenic and recreational experience to the tourist, outdoorsman or other visitor. By its very uniqueness, location, and relative smallness the Long Pines acquires an apparent air of irreplacability and fragility.

The degree and accumulative amount of continuous and widespread development activity that the Long Pines could absorb and still maintain its original wildland values and allure (i.e. during the active development) is limited. However, this is not to suggest that controlled development activities would permanently degrade the essential long-term values of Long Pines

Opposing the above view of "fragility" is the knowledge that Long Pines has sustained several generations of moderate to heavy timber cutting in nearly all accessible areas of its ponderosa pine forests. During recent decades the Long Pines supported from one to several saw mills, all of which does not appear to have irretrievably damaged overall recreational and scenic values. Some might even argue that this historical cutting plus the on-going thinning and timber cutting authorized by the Forest Service has given the Long Pines a scenic park-like appearance.

Figure 12. Long Pines access road used by Mobil Oil received reclamation treatment of native hay mulch to reduce run-off and encourage growth of native vegetation. Group of local planning, county governmental, and private company personnel are shown during tour of the area.

B. Wildlife Disturbances

Wildlife is probably no more disturbed by a single well-disciplined drilling crew than it would be by a routinely noisy party of picnicers, hikers, campers, or hunters. The accumulative effect of a number of simultaneous drilling efforts is another matter.

At least one relatively rare species, the prairie falcon, inhabits the Sioux Ranger District. If exploratory efforts and mining activities should increase beyond some as yet undefined critical saturation point, then both marginally-endangered as well as other species could be adversely affected. The Forest Service land-use plan provides that in Montana (where these raptors reside) all nest sites will be protected against disturbance during the nesting season.

The possibility that uranium mining could adversely influence wildlife interests is being considered. An uranium-related baseline study, primarily involving deer and turkey, was initiated in October 1976 on the Long Pines area by the Department of Fish and Game. The study is sponsored by the U.S. Fish and Wildlife Service and will continue over a three-year period. Specifically the study is designed to gather baseline data for comparison purposes if active mining for uranium should occur on the Long Pines at some future date.

Primary intent of the baseline study is to: (1) identify conflicts between in-situ (solution-mining) techniques and wildlife populations and develop guidelines and alternative methods for eliminating or reducing those conflicts; (2) provide ecological data needed to monitor the effects of solution mining operations on vegetation and wildlife; (3) use the Long Pines area as a model demonstration site for researching the compatability of wildlife, vegetation, and solution mining; (4) identify revegetation techniques that are applicable to solution mining or other in-situ procedures; (5) monitor secondary impacts from in-situ mining activities on wildlife population and develop alternatives to reduce the impacts. (7)

Fish and wildlife of Carter County are considered an important resource that is expected to become more valuable as the ever-increasing growth of outdoor recreation continues. Problems noted include the observation that fish ponds and recreational waters are relatively scarce and inadequate; other problems involve the sometimes less

than desirable relationships between landowners and hunters, often caused by a few thoughtless people. Attention has been brought to bear upon the need for sponsored programs designed to promote good will between sportsmen and landowners. (13)

C. General Impacts

Use of solution mining techniques acceptable under State and Federal regulations disturbs little of the surface and requires a relatively small and readily-removable processing plant. Uranium production areas in southern Texas involve sites of five to ten acres at a time and do not disturb the surface other than what results from pipes, pumps, and treatment plants.

Environmental pressures and degradation that might occur as a result of active solution mining would be assessed under terms of existing State and Federal regulations prior to opening of a mine. Below-surface potential degradation of ground water must be controlled within specific limits by the mining company. Typical precautions to avoid degradation of ground water include the following: (1) hydrological studies to ascertain location, direction of flow, and volume of ground water; (2) monitor wells maintained around the mined area to indicate any escaping mining solution, lowering of ground water levels, and other essential evaluations; (3) confinement of all waste waters to an area within the mining zone; and (4) restoration of ground water through use of mining and water-treatment techniques accomplished to the satisfaction of the licensing authority.

The solution mining process does not require inputs of water, and large amounts of water are not deposited on the surface.

Solution mining plans could only be implemented in Montana after ending of the Moratorium on April 1, 1978 (provided it is not extended), and after completion of the legally-required environmental studies that would assess potential risks and establish a basis for adequate regulation and reclamation.

The probable impacts resulting from open-pit mining are more readily assessed. The open-pit technique disturbs large expanses of surface lands, creates dust, multiple haul roads, large processing plants, and also may interfere with ground water movements or even cause lowering of water levels.

Based on current assumption, and as discussed elsewhere, open-pit mining is not likely to occur on the Long Pines because available uraniferous lignite is relatively low grade and in thin beds. The other Long Pines uranium-bearing formations generally lie too deep and apparently are too scattered for economical strip mining. However, this does not completely rule out open-pit mining that could occur somewhere in the vicinity of Alzada, or nearby, or in the Long Pines region in the future, especially if national energy needs reach a state of urgency that necessitates development of all reachable uranium deposits and if the Federal Government subsidizes mining operations on these low-yield deposits.

As discussed previously, the essentially irreplacable wildland values and the easily-damaged scenic and recreational values of Long Pines could be to some degree temporarily jeopardized by large scale or widespread open-pit mining plus the expected associated activities and processing mills. Such temporary damage would exist at varying levels throughout the active life of the mine. However, there is no reason to assume that even this scale and type of mining development would wreak permanent damage to the area. It appears that Long Pines would recover over the years after cessation of even fairly large-scale mining, and even including surface mining if the operations were conducted under existing regulations, safeguards, and reclamation procedures implemented by State and Federal agencies. Any type of mining on a large scale would, while in progress, to some extent degrade the wild and unique character of an area such as Long Pines. Any losses extending throughout or beyond the life of the mining operations (perhaps 20 years, or so) would represent the trade-off between development and previously-existing environmental values, a circumstance that applies during any development operation.

During strip mining, trees must be removed; obviously, this produces long-term effects (i.e. far beyond the life of the mine). Trees, or even shrubs, are extremely expensive and difficult to re-establish on Northern Plains strip-mined lands. Thus, former forested land would have to be reclaimed into grassland. Strip mines disturb much larger areas than do solution mines. Furthermore, strip mines can typically and functionally disturb or interrupt ground water, while solution mines typically only have to be regulated so as not to contaminate ground water.

Surface mines create dust, a greater number of roads, noise, air pollution, and generally expose a much larger surface area to the development process than would a solution mine. As discussed elsewhere herein, Long Pines uranium deposits appear to offer much greater opportunities for solution mining operations than for strip mining.

D. Management Plan

The Management Plan for the Sioux Planning Unit (containing Long Pines) of the Custer National Forest includes recommendations to the Bureau of Land Management that coal or uranium-bearing mineral lease applications for surface mining (i.e. strip mining) not be approved. This decision is to some extent based on the past ecological degradation that occurred on the Sioux Planning Unit as a result of surface mining and the lack of proven vegetative soil reclamation for this region. Under the Management Plan, requests will be made that Surface Environment and Mining (SEAM) conduct reclamation feasibility studies on the Riley Pass area (surfaced mined in the 1950's - 1960's) to determine techniques and costs for reclamation of surface-ruined areas (10).

E. Above-Surface Potential Impacts Associated With Exploration Uranium Drilling

Informal and brief observations in the Long Pines accomplished by the author in 1977 indicated that above-surface impacts resulting from exploration uranium drilling ranged from minimal to non-existant. Exploration drilling when accomplished by a reasonably conscientious subject company under existing Federal and State recommendations and regulations, does not routinely produce unacceptable degrees of above-surface impacts on wildlife, scenic, soil, water, vegetation, and timber values.

One observation included inspection of the area where a Mobil Oil Corporation drilling crew had earth-damned a small spring-fed draw to provide a better passage route for heavy drilling equipment and a source of water for drilling operations (Figure 13). This newly created pond represents no discernible negative effects and the direct positive impact provides water for mineral-development as well as birdlife and animals.

Construction work on such developmental projects by an energy company is planned and engineered in conjunction with engineering and regulatory personnel of the Forest Service. The engineering work on this dam appeared to be well executed and in no way objectionable to other

Figure 13. Dam built by Mobil Oil Corporation provides a roadway for heavy equipment and water for drilling operations.

uses of the area.

To avoid road damage, heavy trucks and drilling equipment are allowed onto the Long Pines and its primitive dirt roads only during relatively dry summer and early-fall seasons.

At the former drill sites no deep ruts, mud pits, areas artificially bare of vegetation, or litter indicated that drilling crews had operated there during the past summer (Figure 14). Mobil Oil Corporation uses portable mud tanks that circumvent the digging of holes to contain the mud solution during drilling operations. Also, on some drilling sites, tarpaulins are spread to catch drill cuttings that are loaded into garbage trucks and hauled to the disposal site. Thus, post-drilling reclamation is not required because no damage has occurred. Currently, the costs of actual reclamation efforts on the Long Pines are estimated at around $3,000 to $3,500 per acre.

The site of a reclaimed cuttings-disposal pit near a frequently-used road exhibited a degree of rehabilitation that made it undetectable from surrounding terrain unless the viewer knew exactly where to look. While still in use, prior to reclamation, this pit served drilling operations within a circle of several miles. (Figure 15)

One category of continuing potential impact that will in some National Forest areas require on-going attention following drilling operations is the permanent blocking of temporary access routes used by drilling crews and trucks.

During the limited observation time no example of a newly-created and visible access route into formerly "wild" areas was observed except for the one road which the subject company temporarily closed by rolling small logs and poles across it for a length of a hundred yards or so. This served as a sufficient temporary measure; however, this method lacked the permanence required for an efficient long-term closure. Dead poles rot away; they can be removed, etc. Furthermore, this "pole rolling" method of closure compromises the esthetic experience and dilutes the wildland quality of what could otherwise be a serviceable hikers foot-rail into the area. A more permanent type of "closure" uses water-bars of Kelley "humps." These humps have been formed across Long Pines roads to divert water flow (thus avoiding road-rut type of erosion). The earthen humps also discourage future vehicular traffic. Where needed, the

Figure 14. Typical view of reclaimed exploration drill site on the Long Pines Forest. Stake near center of photo marks the drill hole.

Figure 15. Cuttings disposal pit.

roads have been reseeded and mulched with native hay.

F. Below-Surface Potential Impacts Associated with Exploration Uranium Drilling

Concerning potential below-surface impacts following exploration drilling, some opinions assume that existing regulatory and protective measures will adequately administer this activity. Specific drill-hole legislation was developed during the last session of the legislature to cover plugging and reclamation of "shot holes" associated with oil and gas development. Similar legislation covering uranium exploration holes would be helpful. (See Appendix B).

Protective and remedial measures should be specifically formulated to match the uranium-associated geological formations being drilled and applicable regulations should be adequately implemented. At present, on the Long Pines, exploration drill holes are plugged with bentonite and in some locations with a concrete plug additionally installed a few feet below the earth's surface. These plugging techniques currently are based primarily on a combination of Forest Service suggestions and private company understanding of what constitutes a properly-plugged drill hole. In the future, specific requirements may be developed through State and Federal agencies to provide firm standards for reclamation of drill holes by all companies involved in uranium exploration activities.

Forest Service and Mobil Oil Corporation exploration data for Long Pines indicate that during drilling operations no major water-bearing formations were penetrated. Additionally, there is some opinion to the effect that few major water-bearing formations exist underneath the Long Pines area. However, other researched data indicate that resources of potable water, possibly one or more large aquifers, do exist underneath Long Pines. (See Map C for location of wells)

Whether any sizeable water-bearing formations under the Long Pines area would be affected is currently debatable. However, management plans and regulatory measures should always include specific precautions against the possibility of this kind of water degradation.

Spot checks on drill-hole plugging operations with bentonite plus other materials, as applicable, are conducted by the Forest Service. Logs of drilling operations are filed at the Camp Crook, South Dakota ranger station. At any time that future Long Pines drillers are working in water-bearing formations, both the drilling operations and subsequent plugging

operations would be given special attention by Forest Service personnel assigned to the Long Pines.

Currently, plans are tentatively being considered under a portion of the Environmental Protection Agency study to re-drill a selected number of the exploratory holes within Long Pines to check on the adequacy of private company hole-plugging methods.

G. Solution-Mining and Potential Impacts

It is recognized that poorly-conceived or inadequately-conducted solution mining of uranium in some locations of the United States could to some degree degrade both surface waters and underground water-bearing formations. The possibilities generally acknowledged among researchers include the following: (1) seepage from tailing ponds; (2) contamination of surface water; (3) interconnection (and possible degradation) of either different water-bearing formations or different levels of the same formation with drill holes; (4) surface spillage of chemicals; (5) run-off leaching of mine spoil piles; (6) faulty and leaking pipes; etc. (8) (16)

However, it has been demonstrated at the Nation's experimental solution mining sites (Wyoming and Texas) that solution mining of uranium adequately applied and regulated can be accomplished in selected mining areas without non-reclaimable degradation of ground water. A certain degree of ground-water rehabilitation may be required in some specific locations.

H. By-Product Mining

Obtaining of uranium as a by-product from such materials as phosphate and phosphoric acid in central Florida was tried in the late 1950's and early 1960's. The effort was abandoned due to technical problems and lack of profits. Under favorable conditions the on-going thrust of new technology could wring as much as 3000 tons of U_3O_8 per year from the production of phosphate by year 1985. However, many of the phosphate deposits in Florida, North Carolina, and the western states hold low amounts of uranium. (IUS)

The heap-leaching technique is used on various ores that are too low-grade for regular mill processing or located too distant from a mill for economical transport. One researcher estimates an output of 200 tons per year from heap leaching.

Uranium may be recovered as a by-product from the leach solution

associated with copper mining. A processing mill programmed to obtain 75 tons of uranium annually is planned in Utah by Westinghouse and Kennecott Copper Company. Furthermore, recovery of uranium from copper solution is being considered for Nevada and Montana, but due to lower quantities of U_3O_8 the production in these latter two States would be smaller and the feasibility of such an operation less likely.

In some locations, water issuing from mines is processed to recover the uranium therein, but thus far, production has been under 100 tons annually and is not expected to increase.

8. RECLAMATION OF EXPLORATION AND MINED SITES

It is possible to accomplish exploration drilling in a manner that requires no reclamation except adequate refilling of the drill hole. In recent years Mobil Oil Corporation has initiated usage of portable mud tanks and in some locations they have protected soil and vegetation with tarpaulins around the drill hole prior to drilling. Thus, the money that would have gone into reclamation is used in preventive techniques.

Observations on drilling sites dating back to 1975 and 1976, and earlier, indicate that reclamation and re-establishment of vegetative cover has been successful. These drilling sites now support good stands of vegetation and are reclaimed to the point that former disturbed sites can not be picked out from the surrounding terrain. Drilling of the exploratory holes was accomplished by private drilling firms under contract to Mobil Oil Corporation rather than by company personnel; energy companies often use this procedure for accomplishing drilling operations.

Inspection of intentionally non-reclaimed drill-hole location, which was left non-reclaimed as a study site, indicated that such sites will not readily and fully reclaim themselves. Natural revegetation and reclamation would probably require five to ten years. (Figure 16)

Natural Reclamation

Surface or open-pit mining for uranium-bearing lignite was accomplished from 1950 to 1960 on the Sioux Ranger District in South Dakota and 300 acres were disturbed. These strip-mine pits at Riley Pass (located north of Buffalo, S.D.) were not refilled or otherwise reclaimed. Most of the work was contracted by the Atomic Energy Commission under the mining laws of the 1950's which authorized the work but did not include

Figure 16. Bare earth in foreground marks location of refilled drill hole. The site was by design left in a non-reclaimed condition as a study and comparison area. This site is on private land.

requirements for reclamation. (10)

Based on a need revealed in recent information dealing with the documented research value of partially and naturally-reclaimed areas (dating from 1924 and 1933) on Western Energy Company's coal lands near Colstrip, Montana it would seem profitable (in the author's view) to not reclaim 100 percent of surface-mined area at the Riley Pass location and leave a portion for future bontanical comparison studies, etc. (17) Photographs of the mined area at Riley Pass in South Dakota indicate that native vegetation is making a partial recovery in the pit and on the surrounding slopes. In effect, this represents a functional field laboratory of natural reclamation results for study by current and future researchers.

9. TECHNIQUES OF URANIUM MINING

Mining methods adaptable to uranium deposits include: (1) open-pit (strip); (2) underground; (3) solution (in-situ).

A. Open-Pit and Underground

Uranium ore can be economically open-pit (strip) mined to depths of up to 300 feet; theoretically, mining can extend to depths somewhat beyond this, depending upon the ratio of overburden to thickness of ore deposits, percent of uranium, and other related variables. Uranium has been successfully open-pit mined at Shirley Basin, Wyoming (40 miles south of Casper) and elsewhere such as the Highland Mine north of Douglas, Wyoming to depths ranging up to 300 feet. Developers of a strip mine planned for southern Wyoming may attempt to reach 500-foot depths. In future mining efforts, depending on market pressures and increased prices, open-pit mining increasingly may be accomplished at these greater depths. Scarcity of ore, increased demands, and market speculation activities will most certainly push open-pit mining to greater depths both in new ventures and to accomplish the commercial exploitation of cheaper-grade ore deposits in older, already-mined areas.

Open-pit techniques are somewhat similar to the strip mining of coal and are being used in locations such as Highland Mine north of Douglas, Wyoming (Figure 17) and Shirley Basin, Wyoming (Figure 18) where a solution-mining operation was originally used (between 1963 and 1971). The solution mining was discontinued at Shirley Basin because it proved

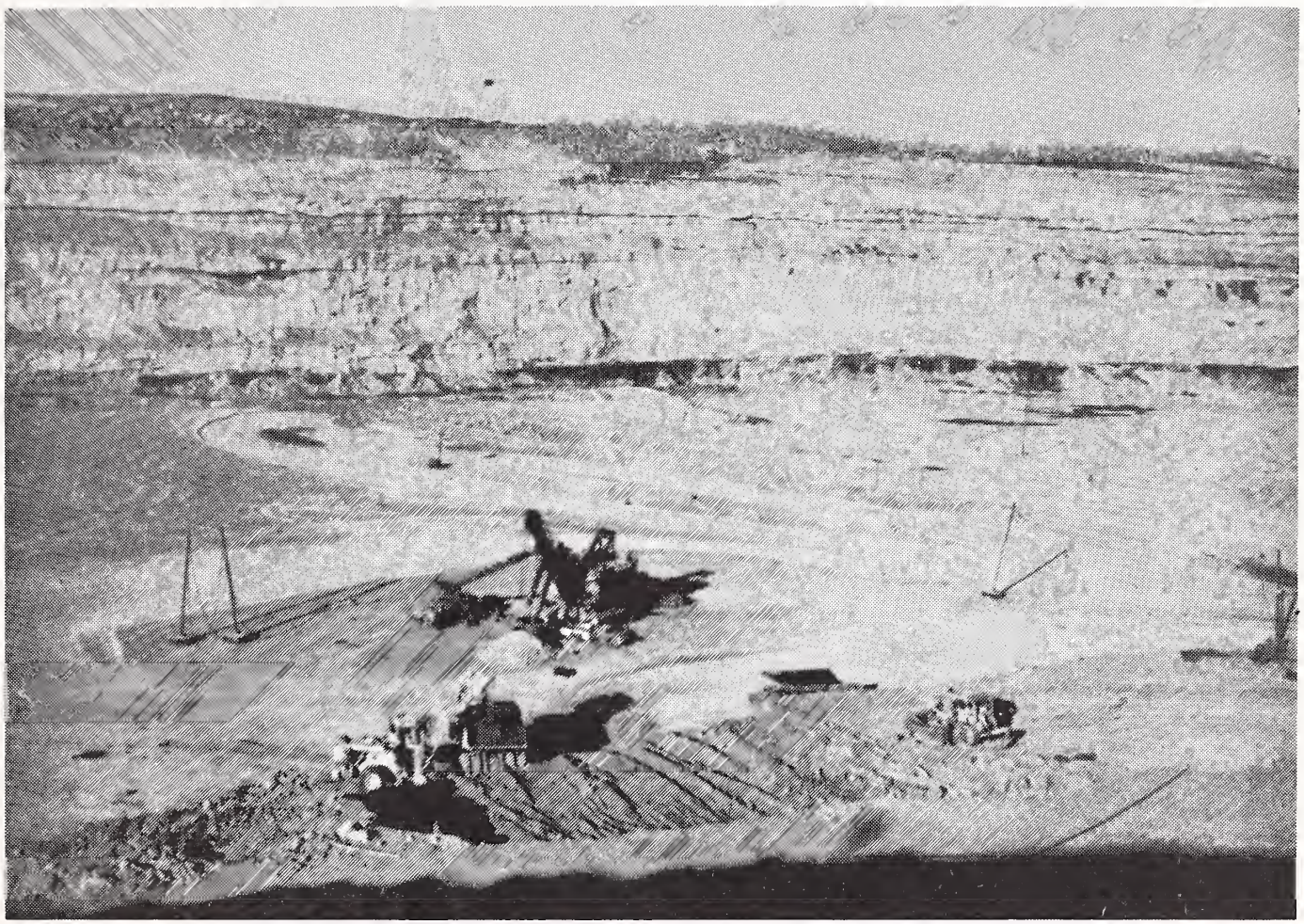


Figure 17. The Highland open-pit uranium mine north of Douglas, Wyoming with pit floor at about 200 feet. Overburden is being removed to uncover ore deposits formerly not considered worth mining.

Figure 18. The Lucky Mc uranium mine at Shirley Basin, Wyoming. Man in foreground uses Geiger counter to determine which material goes to spoil pit and which to the processing mill.

less economical and generally less feasible than open-pit methods which are currently being applied to the specific location and ore deposits.

At the Highland uranium mine, Exxon uses both open-pit and underground techniques in different locations within the same general area. Exxon also has a processing mill in this location; further processing and refining of the yellowcake is done in Illinois and enrichment is accomplished at facilities such as Oak Ridge, Tennessee.

In 1976 there were 16 uranium processing mills operating in the Nation with a total input capacity of 31,000 tons of ore per day. Operating at full capacity for 365 days, and with a recovery rate of 93 percent of the uranium from ore averaging 0.14 percent of uranium, the mills would extract a total of 15,000 tons of processed uranium per year. In actual practice, assuming that the mills operate 90 percent of the time, a total of 13,000 tons of processed uranium oxide (U_3O_8) per year would be made available for shipment to enrichment facilities. An additional 100 tons per year of U_3O_8 might be added to the above total by the in-situ solution mining operations in southern Texas and from experimental attempts to recover uranium as a by-product from phosphoric acid in Florida.

B. Solution Mining

Production solution mining techniques in the United States currently are being used on uranium deposits in the southern Texas region by Companies including Mobil Oil Corporation and Wyoming Mineral Corporation. Wyoming Mineral also has an active experimental solution mine (the Irigaray Project) in northern Wyoming near Kaycee. An additional solution mine may be opening soon in northeastern Wyoming.

Under desirable circumstances, solution-mining may be economically competitive with open-pit methods and is generally less damaging to the environment and more readily adaptable to deep-lying ore deposits. However, for successful solution-mining, several variables must be within acceptable limits and specific measures are necessary to protect groundwater.

Under ideal conditions, some requirements for successful solution mining would include the following: (1) ore should lie in a generally horizontal mode and be underlain by relatively impermeable strata; (2) ore deposits in sandstone formations are the preferred type because they

are permeable. (3) direction and velocity of ground water flow must be known; (4) mineralogy of the ore must be determined so that the mining solution and process can be adapted to it; (5) finally, and obviously, uranium content of ore must be sufficient to deliver the essential margin of profit obtainable from this method of extraction.

Porous sandstone containing the roll-front uranium deposits and lying between an upper and lower layer of shale is the classic example of a formation ideally suited to solution mining.

Injection (input) wells (4-inch to 6-inch diameter) are drilled in a selected pattern around the ore to be extracted. The pattern of the injection wells is based on the physical and geological characteristics of the ore body, ground water, etc. One or more production wells are drilled at a point where the injected solution containing the soluable uranium will be pumped from the earth. The uranium-bearing solution is passed through a recovery plant, the uranium removed, and the solution reconstituted and pumped once again into the ore deposit. (Figure 19)

In earlier operations nitric acid was used as the leaching agent; in more recent years, sulfuric acid was used. Today, the various companies have developed more successful solutions with hydrogen peroxide as the oxidizing agent and ammonium bicarbonate as the complexing agent. The solution-mining process is undergoing constant study, development, and improvement.

Historically, the in-flow wells consisted of stainless steel well casing (3-inch diameter) and the production well was cased with 8-inch stainless steel on its lower 40 feet. Stainless steel screens were placed on the casing just above the ore deposit. The wells were developed by applications of high-pressure jets which were continued until the wells were capable of a satisfactory rate of inflow. Sulfuric acid leaching solution was then applied in the three injection wells. At the same time, pumping was begun on the production well.

In current operations, plastic pipe and improved solutions are used. (Figure 19) Time required to complete the solution mining of a specific section of ore body may be more than a month. The operation then would be moved to a new location within the same ore deposit. However, three to five separate operations may be in progress during the same period of time. When an area has been mined out, the plastic pipes are cut off

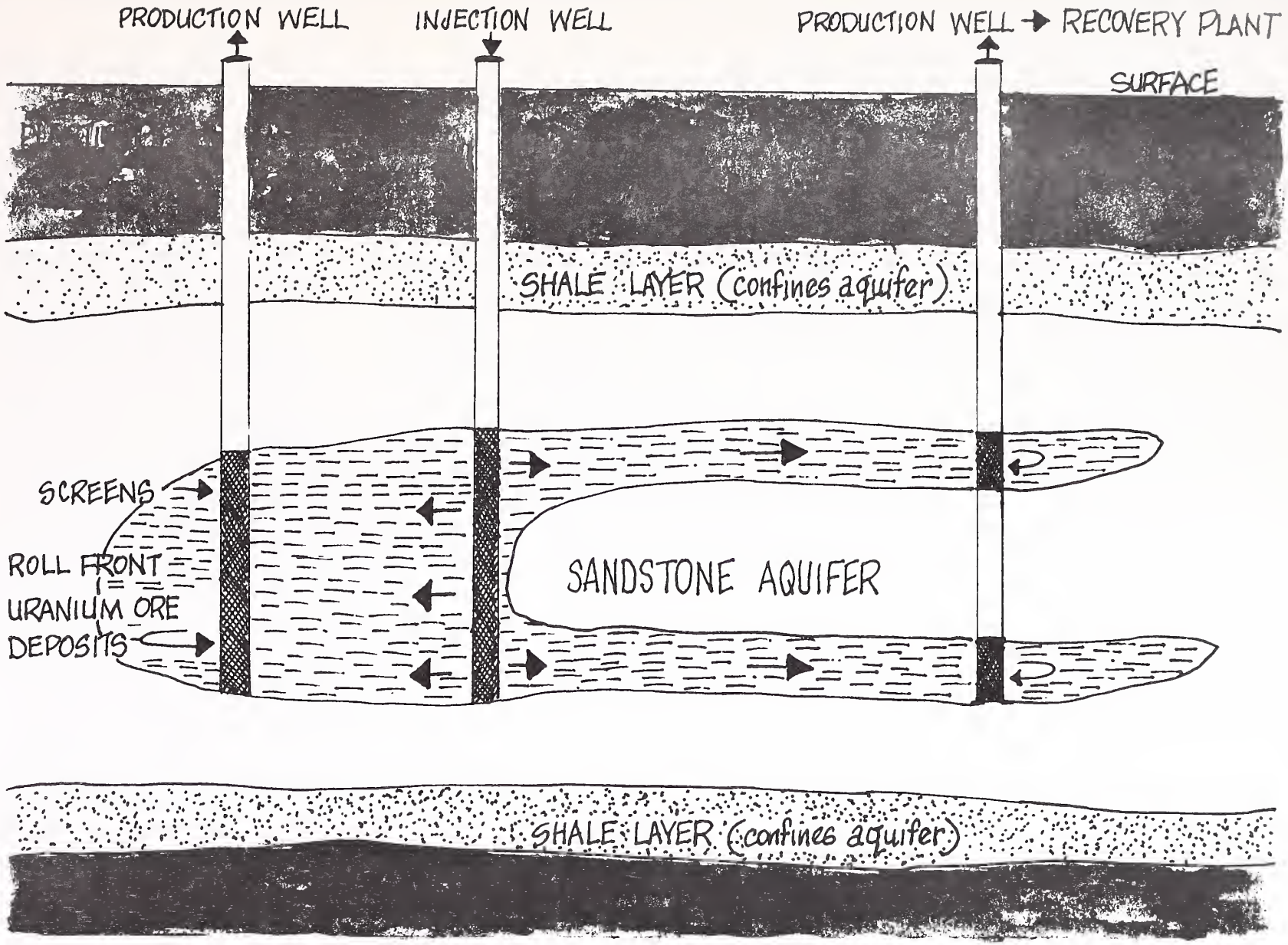


Figure 19. Typical modern solution-mining operation on roll-front uranium deposit (After: Wyoming Mineral Corporation).

below the surface and the field is returned to original use.

Total uranium recovery may equal or even exceed that experienced from underground mining of the same ore deposits. Normally, it is estimated that 100 percent recovery of uranium is feasible within the system of in-flowwells; therefore, skill (i.e. in application of in-flow well patterns, etc) is the primary determination of productivity.

The uranium-bearing solution is processed through a recovery plant which logically would be located at a nearby site not too distant from the mining operations. (Figures 20 and 21)

Although uranium solution mining under acceptable conditions offers a production cost comparable to open-pit mining, the solution method is susceptible to several variables (e.g. ground-water concerns) which can double or triple the cost of production. Solution mining compared to underground mining exhibits greater safety and lessened health risks for workers and reduced costs because operations are above ground and a relatively modest capital investment is involved as compared to underground mining. Precautions to avoid contamination or degradation of ground water offer an important consideration for solution mining projects. Furthermore, in the pre-mining stages during exploration drilling, protective steps may in some situations be required to avoid contamination or cross-connecting of water-producing formations.

Of the three methods, solution mining is the most likely if Long Pines or other areas of southeastern Montana are mined in the future. The roll-front deposits lie relatively deep, indicating that solution mining may be the method of essential merit where such a method is geologically feasible.

C. Methods and Benefits

Because most of the world's deposits of easily reached high-grade uranium ore have already been discovered, it is understood that subsequent resources will be more difficult to locate and more costly to develop. Solution mining techniques which are being perfected in areas of Wyoming and Texas promise to unlock the supplies of uranium that are located too deep or are too low-grade for strip or underground mining. Wyoming Mineral Corporation (Westinghouse subsidiary) is one of several companies conducting research and development of the solution mining process. (19)

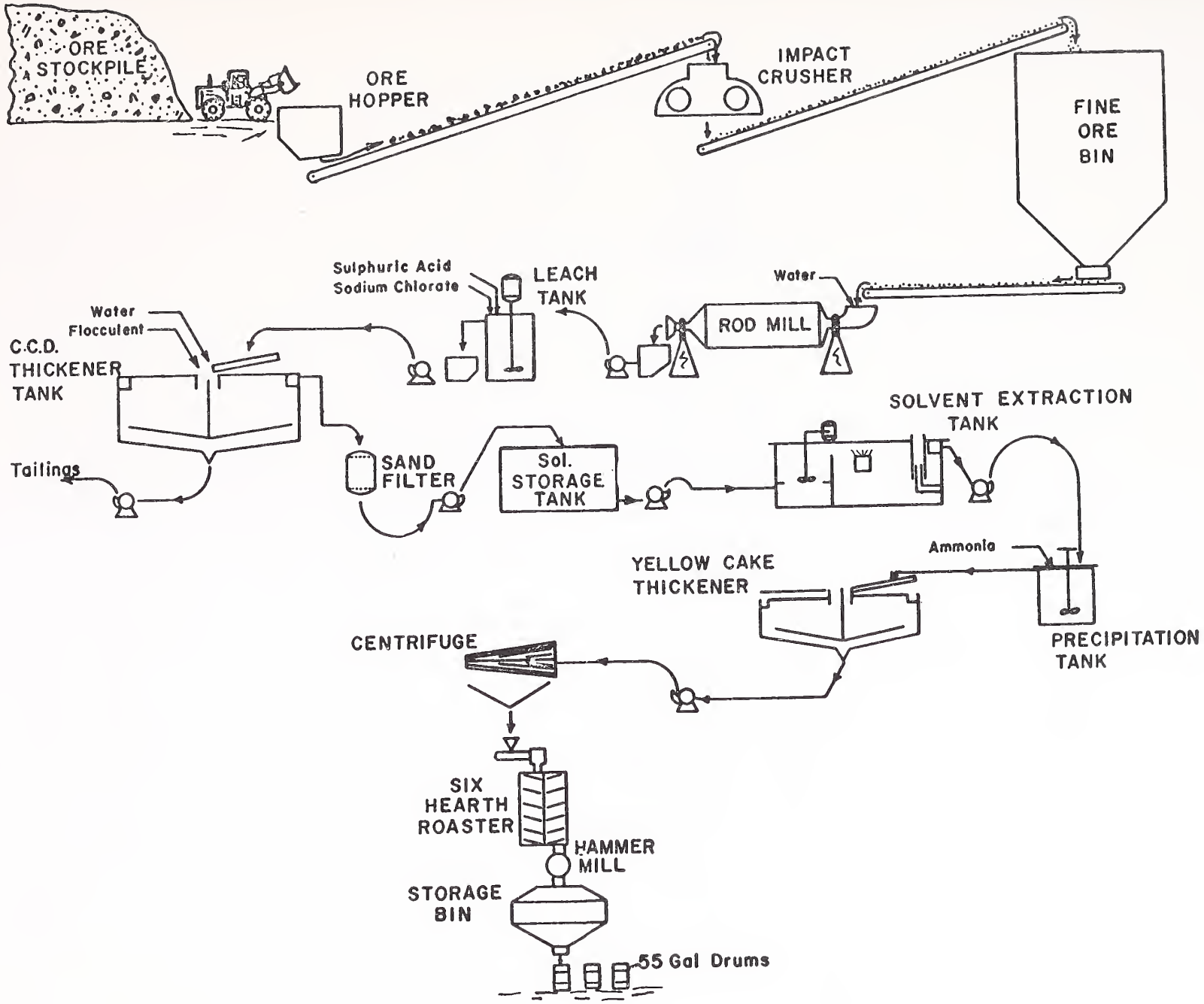


Figure 20. Complete processing and uranium recovery plant associated with a strip-mining operation. (After: Exxon Highland)

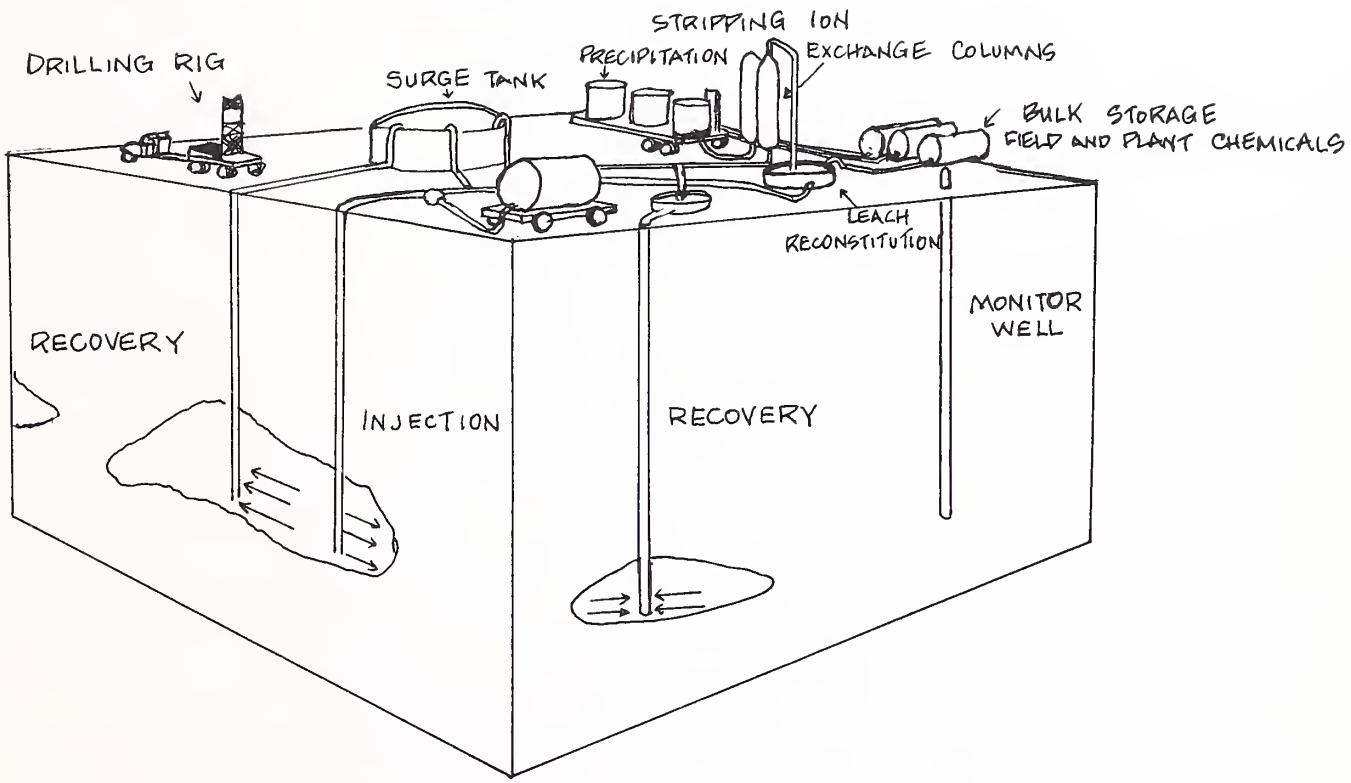


Figure 21. Schematic of uranium recovery plant process associated with a solution-mining operation. (After: Wyoming Mineral Corporation)

Although the practical aspects and economic feasibility of solution mining may compare favorably with open-pit or underground methods under selected conditions, the technical problems associated with solution mining have not been fully resolved. In 1976, the production from two or three solution-mining efforts may have totaled 100 tons. Estimates vary widely, but it is possible that solution mining in the United States will add 1000 tons of uranium in 1980 and 2,000 tons in 1985. Under present conditions, deposits being solution-mined contain around 0.05 percent U_3O_8 and recovery success is estimated at somewhat below 70 percent. As stated elsewhere herein, the proprietary nature of uranium operations significantly retards an up-to-date view of exploration results and solution-mining production operations. (IUS)

A major target of solution mining efforts, the roll-front sedimentary formations were laid down in sandstone and often are contained between nonporous shales or mudstones. The porous sandstone, under favorable chemical conditions, permitted a flow of ground water from which small quantities of uranium precipitated into the roll-front formations. These roll-fronts are somewhat horseshoe shaped and may be on a scale of up to one-half mile, or more, wide.

During modern solution mining, holes are drilled into the ore formation and 4-inch to 6-inch diameter plastic pipes fitted into a predetermined pattern around the part of the deposit that is being mined. The injection solution (hydrogen peroxide as the oxidizing agent and ammonium bicarbonate as the complexing agent) is pumped into the sandstone. The uranium is dissolved and pumped out to the surface through the production well or wells. Flow rates are 25 gallons per minute for small test plants and up to 800 gallons per minute for a medium-sized production plant. Uranium is extracted at a recovery plant and the solution is reconstituted and reused. (19)

10. WASTE DISPOSAL AND SOME SAFETY ASPECTS OF URANIUM DEVELOPMENT AND NUCLEAR ENERGY PRODUCTION

Even under the most stringent control measures, nuclear fuel brings with it the problems of radiation and disposal of waste materials. In an old plant in New York, a number of years ago, it took only five days on the job for workers to reach radiation-absorption danger levels. Tempo-

rary workers who would be routinely changed every five days, were used to overcome this problem. Storage problems are gaining importance and attention as the amounts and frequency of waste materials increase. (20)

Plutonium is acknowledged as the most lethal industrial product known to man, one gram of which equals 35,000 times its weight in sodium cyanide. Some sitings of nuclear reactors have historically occurred close to geological faults and population centers. Here, a trend toward centralization works against us; i.e. grouping three or four reactors in areas than can safely accommodate only one. (20)

Nuclear fusion is a popular and much discussed and heavily researched alternative with a technology that involves combining lightweight atoms, not splitting apart heavy atoms. Thus far, the atomic bomb is the only successful application of fusion. Also, current techniques require 10,000 times more energy input just to begin the fusion process than the fusion process delivers. Obviously this is inefficient. (20)

A. Disposal of High-Level Radioactive Wastes

Used fuel elements from a nuclear plant are highly radioactive and are finally routed to a reprocessing plant. Prior to reprocessing, the fuel elements are held in water storage for three to four months at which time the radioactivity of the fission products with short half-lives has essentially disappeared. A primary goal of reprocessing is to recover the useable fuel remaining after each fuel bundle has helped to produce power for three to four years. A second purpose of reprocessing is to remove plutonium, which forms as an artificial fissionable material within the nuclear reactors. In the future, plutonium may serve as a reactor fuel if the Nuclear Regulatory Commission (NRC) approves commercial recycling of this highly poisonous material.

Plutonium probably would be mixed with either "virgin" or recycled uranium prior to fueling a reactor. Such reprocessing already has been demonstrated on a commercial scale. (4)

Recycling of all used fuel materials would be the ideal approach, but this is not possible under present conditions. Furthermore, the market for materials such as, strontium-90, cesium-137, and cerium-144 is extremely limited. Consequently, these materials will have to be held in protective storage under constant surveillance until safe long-term burial sites can be arranged.

Long-term burial of high-level wastes involves complicated technological problems which arise from intensity of radiation, physical characteristics of the waste material, and production of excessive heat caused by radioactive decay. Many underground storage tanks have built-in cooling systems. Nearly all of the plutonium which was created in the fuel during the reactor operations is removed as a result of reprocessing; thus, storage of significant amounts of plutonium is fortunately not necessary.

Government policy forbids the transportation of high-level radioactive waste in the form of liquids. Eventually all such liquid wastes will be converted into solids -- ceramics, glassy substances, or granular materials -- which are easier and safer to transport.

Providing underground storage for radioactive wastes, mined salt beds have several advantages such as: (1) free of water; and (2) salt responds to heat and flows around the waste containers which seals the radionuclides even more closely. Continuing studies are under way to deal with the urgent problem of waste storage and determine the most satisfactory means of long-term storage. (Figure 22)

B. Underground Mine and Safety

Since the discovery of radioactivity it has been known that uranium mines produce rays and radioactive dust which create a health hazard to which miners may be exposed. Recently laws have been passed that require fairly strict controls on such exposures of uranium miners. Sensitive instruments are being developed (or are already in use) to estimate the radioactive concentration in underground uranium mines. (21)

The new equipment includes a beanie-type battery-operated propeller which the miner wears on his helmet. The propeller sucks air in through a small piece of filter paper. At the end of a day in the mine, the filter paper is sandwiched with a piece of plastic. Radioactive dust on the paper gives off alpha rays that bombard the plastic and weaken it so that when soaked in a suitable chemical, such as lye, small, etched pits are formed. These can be counted, either by hand or by machine, and the number of pits is an indication of how well the mine is being ventilated.

C. Typical Safeguards and Reclamation as Used at the Shirley Basin Complex

The following material originated in 1974 and is offered here as historical data depicting the safeguards and environmental protective

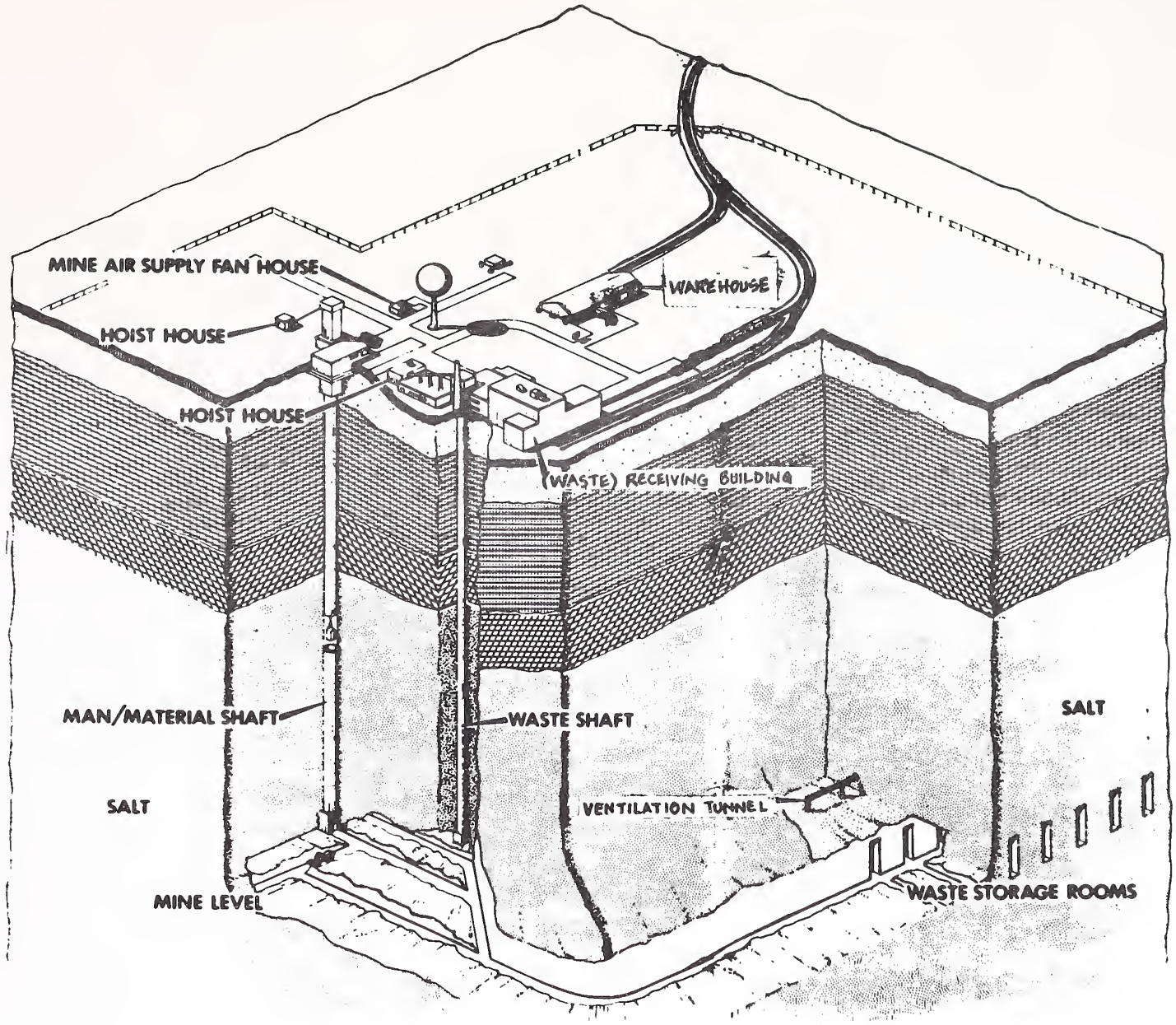


Figure 22. An artist's rendering of a pilot plant concept for disposing of solidified high-level radioactive wastes. The wastes would be stored in salt beds at depths of 1000 to 3000 feet underground and would be retrievable.

measures taken in and around an uranium strip mine. (18)

In 1974 mining at the Shirley Basin location had reached a depth of about 300 feet. It is stated that the dewatering rate (i.e. pumping water from the pit) was 3,000 to 4,000 (gpm) gallons per minute. About 500 gpm of this water was used in the ore processing (at the mill) and the remainder was flowed through a series of settling ponds (for clarification) and then into Spring Creek.

Upon completion of mining, the final pit will not be refilled with earth, but will be allowed to refill with ground water to form a freshwater lake for wildlife usage and possibly human recreation.

Wastes from the processing mill, both solid and liquid, are impounded in a mine tailing retention system. Herein, much of the liquid evaporates and solid wastes are contained for subsequent disposal. The retention system was constructed by damming a natural basin.

Downstream from the dam, several monitoring wells have been drilled and are sampled every 90 days and analyzed for uranium-radium 226, thorium 320, Ph, and nitrates. Thus it can be determined whether or not water is seeping under the dam of the tailing pond. Samples of surface water are taken semiannually and are analyzed for uranium, radium, thorium, Al, chlorides, F, Fe, A, No_3, An, conductivity, and hardness.

Soils and fauna are sampled semi-annually at various areas adjacent to the mine and mill. These samples are analyzed for gross alpha-beta radiation.

Airborne effluents from the mill and mine process are monitored for total particulate mass and U_3O_8. Every 30 to 60 days air samples are taken from both the in-plant and out-of-plant environment. Approximately 31 air sampling stations are established around the mill area and another 18 air sampling stations are maintained outside of the restricted area. (18)

Abatement of dust through use of sprinkling systems and moving air is accomplished routinely in underground uranium mines and in critical areas of the processing mills. Workers in potentially hazardous dust areas wear protective masks with battery-powered filtration systems which pass a moving stream of clean air across the worker's face.

The above is only a brief view of the various kinds of safety techniques currently in use at today's uranium mines and mills.

11. SOME SOCIOECONOMIC IMPACTS AND CORRECTIVE MEASURES

A. General Discussion

In the event of a solution-mining operation either in the southeastern corner of Montana or in adjacent uranium lands, plus a recovery plant and processing mill, the potential impacts (both positive and negative) to adjacent small and isolated communities could be considerable. Positive impacts include the influx of "new" money into the region; negative impacts include the accompanying influx of new people and their needs and expectations for services to be supplied by local communities.

The construction and operational phases of a solution-mining complex employ fewer employees than do parallel phases of an underground mine or a strip mine. The recovery plant and processing plant developed to serve a solution mine would require a relatively small on-going work force, probably on the order of 70 personnel for each facility, or at any rate it would be considerably less than 100 personnel for each solution plant complex. It is logical to assume that any solution-mining operation would include an uranium recovery plant located as close as possible to the actual mining area. If uranium areas within the northern Wyoming-Montana-South Dakota uranium region are developed, the building of uranium processing plants, living quarters, and the associated influx of new residents would follow and might pose a relatively large-scale impact for the scarce and isolated communities located in these general regions.

The small number of drilling company employees associated with the Long Pines and local-area uranium explorations generally live during the summer months either in a mobile home park east of Ekalaka or in local motels. It is not unreasonable to assume that perhaps the majority of long-term employees for a solution mine-and-mill complex might conveniently live in mobile home developments in one or more isolated areas near the work site.

A typical uranium strip-mine operation such as the Highland Mine, Douglas, Wyoming may employ 120 workers assigned to shifts and with the processing complex operating 24 hours per day and seven days per week. The Highland underground mine employs a total of about 150 employees. Thus, a complex including a strip-mine and underground

mine plus the processing facility might totally employ 270 or more people. For comparison, a solution-mining operation would employ considerably fewer workers, perhaps as few as 70.

The processing mill located in a strip-mine complex consumes about 2800 tons of uranium ore per day. On an average, in order to obtain 2 pounds of yellowcake at the Highland Mine near Douglas, Wyoming it is necessary to process 2,000 pounds of strip-mined ore material. (9) At the strip-mine and processing-mill complex at ShirleyBasin, Wyoming it is estimated that each 2000 pounds of ore delivers two to three pounds of yellowcake.

If an uranium mining-and-processing complex should develop in Carter County, or elsewhere within the northern uranium lands, it is projected that the sparsely-populated region would likely experience a mobile home development. Shirley Basin Townsite is a multiple-company town near the mines and occupied by around 630 people, including employees and families. Many similarities exist between the Shirley Basin area and the uranium lands of Carter County, Montana; western South Dakota; and northeastern Wyoming. These contiguous regions are characterized by sparse population, remoteness from any sizeable towns, limited or even an absence of year-around maintenance on essential access roads, lack of social and creature-comfort amenities near the mine areas, limited housing facilities in existing communities, lack of shopping facilities, etc.

The normally discussed functional version of a "townsite" usually includes mention of at least one each of the more basic and essential community services such as grocery, gasoline station, cafe, motel, church, school, and so forth. The less-used services including dental, medical, stores other than grocery, recreation outlets, etc, would be obtained in towns located within one-day travel distance of the mine and complex area.

Companies such as the Lucky Mc Mine routinely offer a type of subsidy pay which is based upon distance that the worker must travel from home to job. This offsets travel expenses of workers who must live and work in remote locations. The Shirley Basin complex is about 40 miles from the nearest town (i.e. other than the company-owned Townsite which is adjacent to the mining complex).

Salaries generally available in the uranium industry are comparable to those of the coal industry. An average worker employed to maintain diesel-powered mining vehicles at a central Wyoming uranium open-pit mine

would earn around $8.30, or more, per hour and probably be paid some regular cost-of-living adjustments, travel subsidy, etc. Generally, both in the uranium mining industry and in western coal mining, construction workers and field-production workers may routinely earn median salaries of around $19,000 to $22,000 annually.

Black Mountain Village developed by the Missouri Basin Power Project (MBPP) near Wheatland, Wyoming is discussed here as another example of a company-subsidized town that serves a new lignite-fired electricity-generating complex. The Village is a housing development built for the MBPP construction work force. Included is a 200-unit bachelor quarters and dining hall, approximately 700 mobile home pads, and a 300-unit travel-trailer and camper park. (22)

The MBPP believes that this adjacent housing has assisted the project by attracting a more-highly qualified worker and resulted in reduced worker turn-over and better productivity. The Project estimates that it will eventually obtain a return of approximately 75 percent of the actual costs on its investment in building the housing facilities at Black Mountain Village.

For Black Mountain Village the community planning began two years prior to initiation of the actual construction work. MBPP worked closely with city and county planning and administrative officials to assist them in obtaining public financing for the upgrading of existing utilities and services. (22)

Personal discussion by the author with energy company operational and management personnel indicates that some companies are not overly anxious to become directly involved in creation of a new community, preferring to depend upon private developers to both finance and build the town with only statistical and planning assistance offered by the energy company. Other energy companies, when faced with the problem of an isolated region, either through necessity or otherwise, may become directly involved in bringing a new community into existance.

The question sometimes arises as to whether a specific energy company will financially help the local community with financing and planning of various essential services, new recreational facilities, etc. The answer, presumably somewhat typical, is that private companies generally appear to consider the 30 percent Montana severance tax as being of sufficient magnitude to relieve them (the private companies) of

obligation for such assistance.

B. Assistance to Regions Experiencing Uranium Development

The U.S. Congress, under the Community Development Act, has authorized the following legislation to offer assistance to regions impacted by expanded coal or uranium production. (23)

Section 306

(a) When it is determined that employment in the coal - or uranium-mining industries, or those related thereto, has increased by 8 percent or more over the 1976 level and that the area will require additional public facilities, services or housing, then the Governor or Chairman of any Indian tribe may designate such an area within his jurisdiction as an "energy-impacted region." The Governor or Chairman shall at this point notify the Administrator of the Farmers Home Administration in regard to this designation, and shall describe the boundaries of the impacted region and describe existing and anticipated socioeconomic impacts.

(b) Following designation of an energy-impacted region by the Governor or Chairman, the Administrator shall accomplish the following:

"(1) Make available from available appropriations one hundred percent federally-funded planning grants for such regions for the purpose of developing a growth management and housing plan for the impacted region. Such plan shall indentify anticipated levels of coal or uranium development within the region, the nature and extent of projected socioeconomic impacts and the need for temporary and permanent housing sites and facilities. If the Governor concurs, such grants may be made directly to counties or other appropriate political subdivisions including areawide councils of local government and designated substate planning and development clearinghouses. If the Administrator finds in writing after consultation with the Governor and local officials that particular grants are unnecessary, the Administrator may veto grants on a case-by-case basis:

"(2) Transfer funds authorized for this section to the Farmers Home Administration to -

"(A) Acquire land by purchase, donation, or condemnation, and develop and transfer acquired land to any State or to a political subdivision thereof, or to any qualified housing contractor if he determines that such transfer is an integral and necessary element of an economically-

feasible plan for the development of housing in the energy-impacted region. (The foregoing is subject to the approval of the Governor or Chairman.) Such activities shall be accomplished under such terms and conditions as the Administrator shall require, which may include transfer of land with or without monetary consideration: Provided, that, after completion of the housing project, the recipient of the transferred land shall pay to the Administrator the fair market value of the land prior to development. Land development shall be limited to site preparation work and construction of access roads and off-site improvements such as sewers and water line extensions which the Governor or Chairman determines are necessary or appropriate to the economic feasibility of a project; and

"(B) Provide technical assistance to any State or political subdivision thereof for the development of housing, sewers, water systems, and other public facilities.

"(C) In selecting land pursuant to paragraph (b) (2) (A) of this section for acquisition and development, the Administrator shall give priority to acquiring tracts of land which were uninhabited or which were previously mined prior to the date of enactment of this Act. No part of the funds provided under this section may be used to pay the actual construction costs of housing.

"(d) The Administrator of the Farmers Home Administration may carry out the purposes of subsection (b) of this section directly or may make grants and commitments for grants and may advance money under such terms and conditions as he may require to any State, or any department, agency, or instrumentality of a State, or any public body or nonprofit organization designated by a State.

"(e) To expedite the construction or rehabilitation of housing in designated energy-impacted regions, the Administrator of the Farmers Home Administration or his designee shall convene a strike force in each designated energy-impacted region made up of representatives of the Governor or Chairman, local political subdivision, and each of the Federal agencies or departments that have existing programs relating to housing, public facilities, reclamation of abandoned mined lands, flood insurance, and such other programs as the Administrator deems relevant. The strike force shall be empowered to waive elegibility requirements for assistance under such programs on a case-by-case basis for applicants from the energy-

impacted regions: provided that, no eligibility requirements relating to civil rights or to protection of the environment may be waived. The administrator of the Farmers Home Administration or his designee shall serve as the Chairman of the strike force and shall prescribe the terms and conditions under which waivers are approved.

"(f) Within three months of designation of an energy-impacted region, all coal- or uranium-related companies operating within the region or transporting large quantities of coal or uranium through the region, shall prepare a report to the Administrator. Such report shall include projected employment demand over the life of the operations, annual projected influx of employees from outside the region, and projected annual coal or uranium production. Copies of the report shall be filed with the Governor or Indian tribe, the Administrator of the Farmers Home Administration or his designee, and appropriate county or local officials and shall be available for public review at each county courthouse within the energy-impacted region.

"(g) There is authorized to be appropriated annually for eight years to the Administrator the sum of $150,000.00 beginning with fiscal year 1978, which shall remain available until expended for the purposes of this section.

12. MARKET DEMANDS AND DEVELOPMENT

Whether Long Pines or any of the adjacent regions are ever solution-mined depends upon identifiable variables: market demand; percent of uranium per ton of ore; ease of recovering the uranium; and technological improvements in the solution-mining process and the effective application of such improvements.

Each of the variables and its individual importance and trade-off value within the complex of variables is directly related to and balanced by all other associated factors. Today's increasing market and solution-mining advancements may encourage mining of the poorer-grade uranium that is either located in scattered "blanket" deposits or is in other ways difficult to recover.

Market manipulation and also inherent market demand rising on the tide of National and Free World needs are the variables most likely to escalate and cause active mining of southeastern Montana and adjacent

states uranium. The known supply of uranium reachable by present mining methods is not expected to fulfill allof the anticipated needs and demands. As stockpiles of uanium dwindle, prices go up, and yesterday's low-grade ore considered "not worth mining" may become tomorrow's profit-producing and energy-viable resource.

According to a Federal energy official, the United States will have to locate and develop an additional 400,000 tons of uranium ore by 1990 to provide fuel for the Nation's 64 commonly-in-use light water reactors (LWR's) which would have to provide all of our nuclear-derived energy if the "breeder" reactor programs and new plants are either delayed or canceled. This needed 400,000 tons of uranium ore is almost equal to the total known United States reserves at this point in time. (12)

Who owns the Free World's uranium? According to a recent National news report the so-called "uranium-oil companies" of the United States in 1977 owned 71.8 percent of the Nation's uranium. These major oil companies are said to own approximately 317,000 tons of United States uranium reserves which total approximately 441,500 tons. (24)

Stimulation or depression of the uranium market by various types of maneuvering and political decision is evident in the following material from a major news article:

> "A Wall Street Journal editorial about the policy (halting the plutonium reprocessing and slowing down of breeder reactor programs) concluded that plutonium reprocessing is a waste of money. It would cost $500 million for the government to complete the Barnwell, S.C. reprocessing plant. 'No one in the nuclear industry has ever made a profit,' according to the editorial.
>
> "Something about nuclear power has clouded ordinary commercial judgements, and it looks to us as if Mr. Carter is stopping the industry from doing it again."
>
> The H.C.N., article continues: "Westerners have been wondering whether delay of the breeder reactor, which produced its own fuel in the form of plutonium might increase the need for uranium fuel. Wyoming State geologist, Dan Miller predicts that uranium mining activity in Wyoming would be stimulated by the new policy." (13)

Scatter reflections from this kind of "stimulation" may eventually reach into more than one portion of the uranium lands of the Northern Plains.

A more recent article reflects the rebound reaction to the slow-

down order on breeder reactor programs:

> Despite President Carter's call for a halt to development of the breeder reactor, the U.S. House Science and Technology Committee voted 38 to 0 to continue funding of the Clinch River, Tennessee plutonium breeder reactor.

However, even without the Clinch River demonstration project, as a British nuclear engineer stated, the United States will spend 10 times more on breeder research than any European nation. The British spend around $44 million per year on breeder programs. Not counting any funds for the Clinch River breeder demonstration project, the United States will still spend about $540 million each year on breeder projects. (24)

Building of the Clinch River breeder plant, which would produce 350 (MW) megawatts of power, is far from being a dead issue. Congress appeared to be moving ahead with plans to fund the project in the amount of $150 million in 1977. (14)

13. CONCLUSIONS

A. Above-Surface Impacts

Considering Long Pines as a sample Northern Plains exploration area, observations indicate that the subject company (Mobil Oil Corporation) and their field personnel reflect a commendable attitude of concern for the many small or seemingly insignificant environmental items that if ignored could and likely would snowball into adverse effects.

B. Below-Surface Impacts

Available data indicates that below-surface impacts such as potential contamination or interconnection of water-bearing formations have not occurred and thus have not endangered Long Pines ground waters. However, even if present, these types of occurrences at Long Pines might not be readily detectable. During the exploration phase, Long Pines had no evaluation drill holes (or monitor wells) that were assessed over periods of time coinciding with and subsequent to exploration drilling, nor were there any suitable nearby active and regularly-used domestic water wells that might effectively indicate damage to water-bearing formations such as the Fox Hills sandstone.

Plans may be under way through Federal sources (EPA) to consider redrilling of a few of the Long Pines uranium exploration holes to assess refilling techniques used by private company drilling crews. As discussed

elsewhere herein, Forest Service personnel at Long Pines routinely conduct spot checks during the filling and plugging of drill holes. Holes are typically filled with bentonite and some or all may be plugged about three feet below the earth's surface with concrete.

Suggestions deemed by the author as being worthy of consideration for preventing adverse impact on Montana's water-bearing formations, include: (1) development by the State of Montana of specific and adequate requirements for refilling of uranium exploration drill holes. At present there are no specific and comprehensive requirements that cover the materials and methods for refilling of such drill holes; (2) licensing of private contractors that do exploration uranium drilling in much the same way that water-well drillers are currently licensed in the State of Montana. This measure could provide additional assurance of protection against below-surface potential impacts; (3) filing of official logs with applicable agencies and including the description of activities involving water-bearing formations and manner in which the drill holes were plugged; (4) providing public access (on a need-to-know basis) to pre-mining surveys. In actual practice, prior to solution mining of uranium, the subject company must thoroughly survey and document subterranean geological structures. Such normally-proprietary knowledge could be immensely beneficial to research, regulatory, and management personnel involved in planning post-mining reclamation of any affected aquifer. Worthy of consideration is the suggestion that such surveys conducted and documented by private companies be considered public knowledge and made readily accessible to those needing this material. It could be argued that such data logically may not always come under the category of "privileged information" because the subject company at this point in time (pre-mining) may well have passed the point at which company protection of on-scene geological data would be deemed reasonable.

C. Monitoring and Regulation of Solution Mining

The Moratorium on solution mining of uranium in Montana may have provided additional time for development of studies and regulatory measures and perfecting of techniques designed to ensure additional groundwater protection. The specific resulting benefits of the Moratorium are unknown at this time. The Moratorium was scheduled to end as of April 1, 1978.

Solution mining technology is being upgraded and modernized by several of the involved private companies. Experimental and production plants are located primarily in northern Wyoming and southern Texas. Although studies are aimed primarily at increasing the efficiency and economic feasibility of the process, they also have tended to develop less caustic types of solutions (i.e. less potentially damaging to ground water than the usage of old-style sulfuric acid solutions).

At least some individuals within State regulatory agencies consider current Montana laws adequate to control anticipated impacts resulting from solution mining of uranium; however, judging from currently available literature, there are at least some who see the need for additional regulatory and protective measures.

The Yellowstone-Tongue APO study recommended that at a minimum the new uranium-oriented regulations should include the monitoring of test wells during the mining operation, and restoration of any affected water-bearing formations following solution mining. Because solution mining of uranium might involve principal water-supplying formations in southeastern Montana, it is considered a necessity that monitored well data be made available to State and Federal regulatory agencies. This data should be accumulated during the exploration phase and prior to mining (baseline), during mining, and also on a post-mining basis.

D. Higher Prices and Increased Uranium Activity

According to the Energy Research and Development Administration (ERDA) the market value of yellowcake (i.e. refined uranium oxide prior to the enrichment stage) is cycling from $35 per pound to $59 per pound. Current estimates (1977) indicate that solution mining can promote yellowcake production at around $15 per pound under average conditions. Exact demand for uranium is difficult to predict, but a conservative estimate indicates that there will be less than enough uranium to meet the demand, thus producing an up-swinging market. (Figure 23)

Rising market demands will continue to influence the value of ore deposits and will ultimately decide both the initiation and extent of uranium mining and processing operations within the Northern Plains "uranium lands." The value of all uranium deposits is increasing and certain deposits will be considered for mining when their potential market value exceeds the operational costs of mining and production. Exactly when this

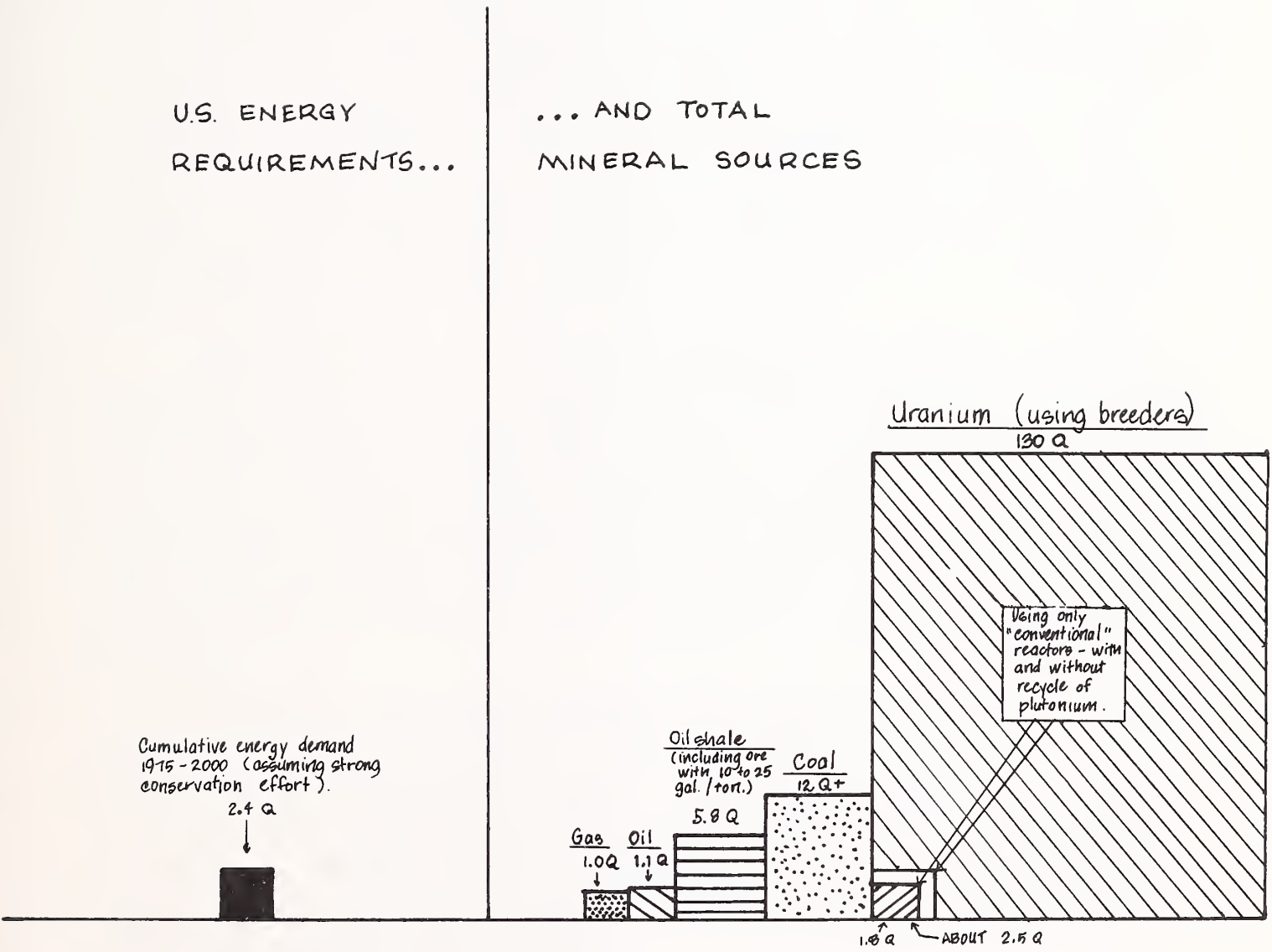


Figure 23. The energy available from various resources in the U.S. compared with ore projection of the Nation's needs between now and the end of the century.

point may be reached for a given ore deposit depends upon market demand and the several variables previously described. Federal government support of uranium mining or an increased energy crunch of some unforseen magnitude and urgency also could become important additional factors.

Forecasts derived from investment sources indicate that some officials believe nuclear fuel may be producing 25 percent of the Nation's energy needs by year 1985, which is a considerable increase over the 10 percent delivered by nuclear fuel at the present time. Further predictions, contrary to these optimistic figures, indicate that existing uranium reserves could be depleted by as early as the 1990's. However, the development of successful breeder reactors (producing their own fuel) would work in favor of increased electrical power derived from nuclear sources. As mentioned elsewhere herein, uranium prices have undergone sharp increases. Projections indicate that prices could reach $100 per pound by the end of this decade. (25)

Investment sources report that higher uranium prices will afford the greatest benefit to: United Nuclear (NYSE); Reserve Oil and Minerals (OTC); and American Nuclear (OTC). However, these sources point out that these listed companies represent extremely speculative issues. Other companies that would participate in long-run growth of uranium demand include: Kerr McGee and Gulf Oil (both Big Board) which have the largest reserves and are considered as more conservative avenues for the investor. (25)

Conservative projections might well include the observation that although an increase in mineral exploration and related activities are likely, the actual opening of uranium mines and building of new processing plants and the resulting socioeconomic impacts are in the somewhat distant future for most areas of the Northern Plains uranium lands unless significant market pressures and National urgency takes an even sharper upturn than that now being observed.

E. Uranium Production

During the period of 1972 to 1977, the annual production of uranium (yellowcake) in the Nation has been around 12,000 to 13,000 tons, and is estimated to reach around 18,000 tons of uranium by 1980 and around 23,000 tons by 1985. (IUS)

F. Capital Concerns

During the past decade two major and revealing trends marked the

uranium industry: (1) major oil-and-energy companies assumed dominant roles in uranium raw materials operations; (2) electrical power companies became owners and financial backers of uranium mines and processing mills.

G. Production of Nuclear Energy

Future exploration efforts for uranium and progress in the production and application of nuclear energy rest essentially upon the same supports as do other types of energy-development efforts which include: Governmental decisions in regard to nuclear power; taxation; general structure of the energy industry; environmental constraints by Federal and State regulations and citizen groups. Some observers conclude that the various companies involved in nuclear energy will be able to develop the capital required to proceed with exploration, mining, processing, and marketing of uranium.

14. LITERATURE CITED

(1) State of Montana Bureau of Mines and Geology. Directory of Mining Enterprises for 1975. Bulletin 100. p. 27.

(2) Jarrard, Leonard D., 1957. Some occurrences of Uranium and Thorium in Montana, Montana Bureau of Mines and Geology, Montana School of Mines, Butte. 90 p.

(3) Denson, N.M. and Gill, J.R., 1965. Uranium-Bearing Lignite and Carbonaceous Shale in the Southwestern Part of the Williston Basin -- A Regional Study. U.S. Geological Survey Professional Paper 463. U.S. Government Printing Office. 67 p.

(4) Dukert, Joseph M. Nuclear Power and the Environment. 1976. ERDA. 87 p.

(5) Simmons, H. The Economics of America's Energy Future. 1975. U.S. Energy Research and Development Administration (ERDA). 61 p.

(6) Dukert, Joseph M. High-level Radioactive Waste: Safe Storage and Ultimate Disposal. 1975. ERDA. 23 p.

(7) Energy Research Information System. Projects Report. The Old West Regional Commission. November 1977. Vol. 2, No. 3. p. 81.

(8) Willard Owens Associates, Inc. 1977. The Potential for Ground Water Contamination Due to Uranium Exploration and Solution Mining. Section 208 Areawide Waste Treatment Management Planning Grant (Environmental Protection Agency).

(9) Walcheck, K., 1975. The Long Pines. Montana Outdoors, Department of Fish and Game, March - April, p. 15-19.

(10) Exxon Highland Mine Bulletin, 1976, Casper, Wyoming.

(11) U.S. Forest Service Dakotas Planning Use Team, 1976. Environmental Statement Sioux Planning Unit Multiple Use Plan; Sioux Ranger District, Custer National Forest, Northern Region, 129 p.

(12) The Christian Science Monitor, Club of Rome Hails Carter Energy Plan, April 28, 1977.

(13) Soil Conservation Service, 1976. Carter County Conservation District, Long Range Program. p. 26, 66.

(14) High Country News, 1977. New Nuke Policy Has Something for Everyone. Vol. 9, No. 8, p. 11.

High Country News, 1977. Uranium Shortage. Vol. 9, No. 9. p. 10.

High Country News, 1977, TVA, Union Carbide Plan Uranium Mines in S. D. Vol. 9, No. 10. p. 7.

High Country News, 1977. Breeder Reactor Revived, Vol. 9, No. 12

High Country News, 1977. Wyoming Rejects Uranium Mine. Vol. 9, No. 15. p. 11.

(15) Nations Center News, August, 1977. Uranium and Coal Prospecting Permits. Vol. 2, No. 38, p. 1.

(16) Clark, Don A., 1974. State-of-the-Art: Uranium Mining, Milling, and Refining Industry; Environmental Protection Technology Series (E.P.A.). Robert S. Kerr Environmental Research Laboratory. 114 p.

(17) Montana Department of State Lands, 1977. Draft Environmental Impact Statement for the Proposed Expansion of Western Energy Company's Rosebud Mine Into Areas A and E. Vol. II. Appendix D-5.

(18) Utah International, Inc., 1974. Uranium Mining Techniques and Environmental Implications; presented at AIF, San Francisco, June 19, 21 p.

(19) Uranium Solution Mining, 1976. Wyoming Mineral Corporation.

(20) Clark, W. Energy Office, State of California.

(21) Kastner, J. Nature's Invisible Rays. ERDA. Oak Ridge, Tennessee. 44 p.

(22) Basin Electric Power Cooperative, 1977. Annual Report.

(23) Community Development Act. 1977 U.S. Congress.

(24) U.S. News and World Report, 1977. Carter's Nuclear Policy: Running Into Trouble. Vol. LXXXIII, No. 1, p. 52.

(25) Sargent, D.R. 1977. Future Looks Good for Nuclear Power. Billings Gazette

(26) Stout, Koehler, S., 1961. Montana Mining Law, Bulletin 22. Montana Bureau of Mines and Geology.

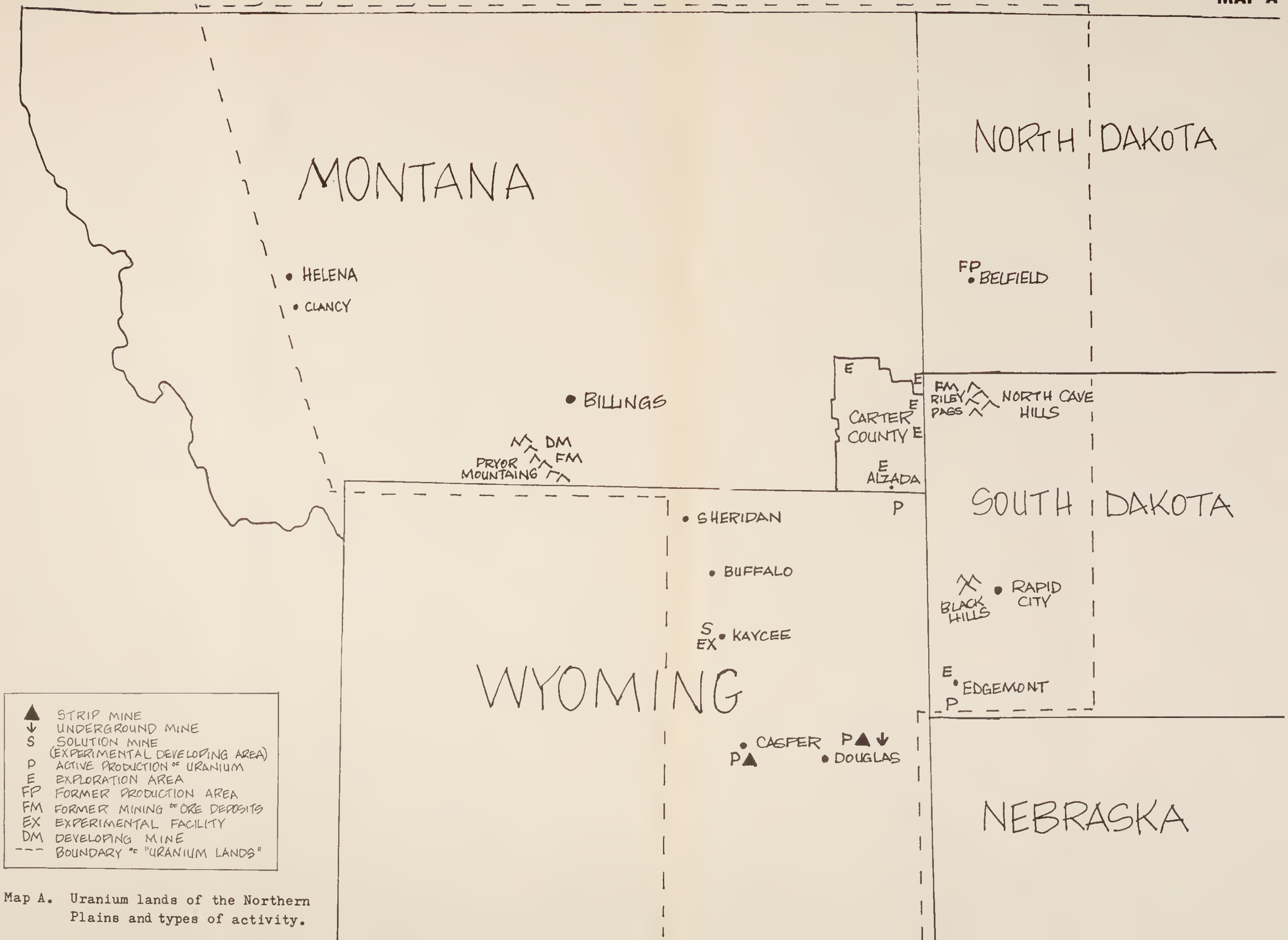
(27) Northern Plains Resource Council, 1975. Energy Companies Active in Montana.

(28) Bavarskis, J. The BLM's Big Dilemma: Tussle Over Federal Lands. Planning, June 1977. American Society of Planning Officials. Volume 43. No. 5, p. 11.

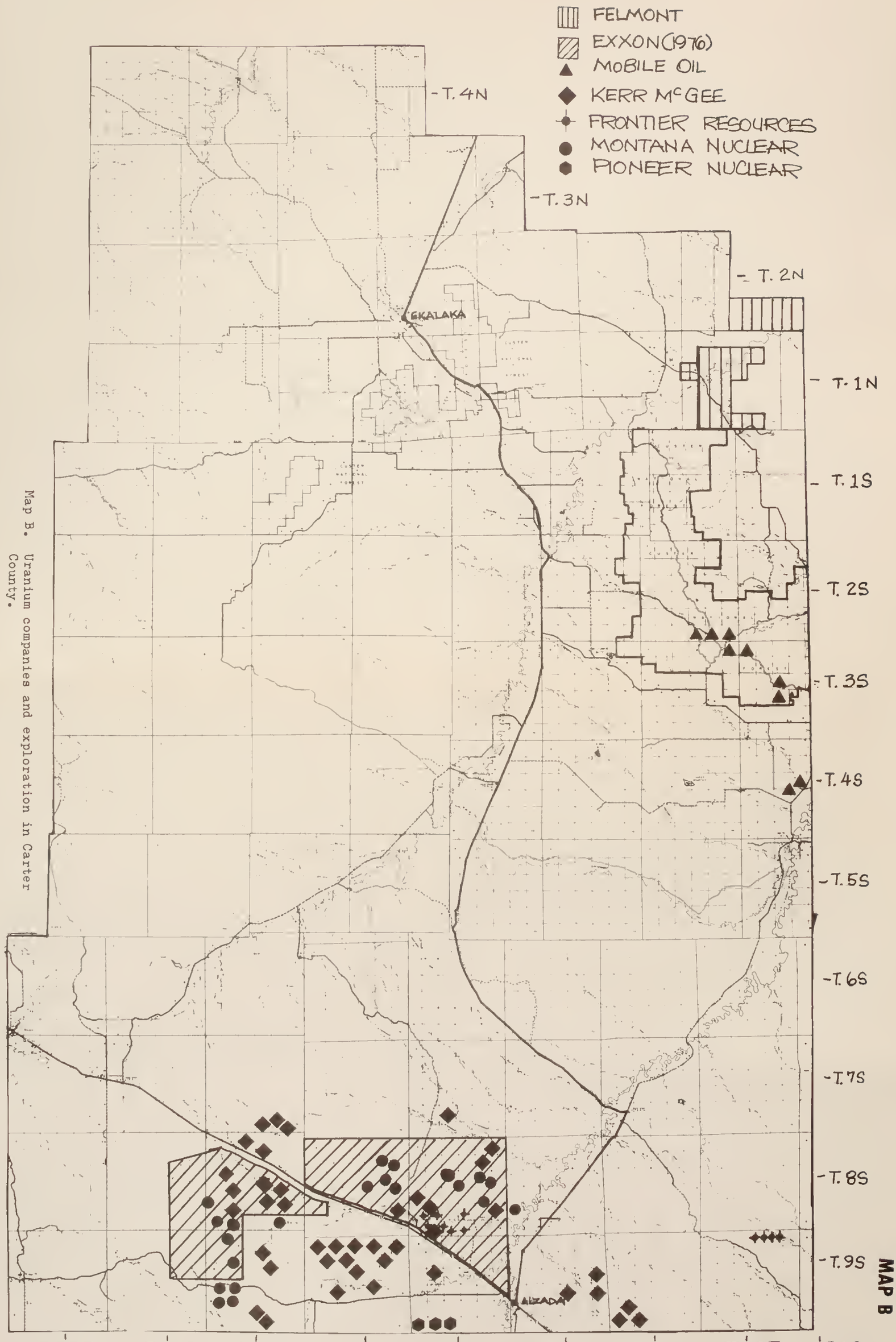
(29) Stinson, Thomas F. 1977. State Taxation of Mineral Deposits and Production. Economic Research Service. U.S. Department of Agriculture. 44 p.

(30) Uranium Solution Extraction: The Process and the Law, February 1977. Report to the Governor and Montana 1977 Legislature by the Department of Natural Resources and Conservation.

(31) National Energy Outlook, 1976. Federal Energy Administration. p. 253-271.



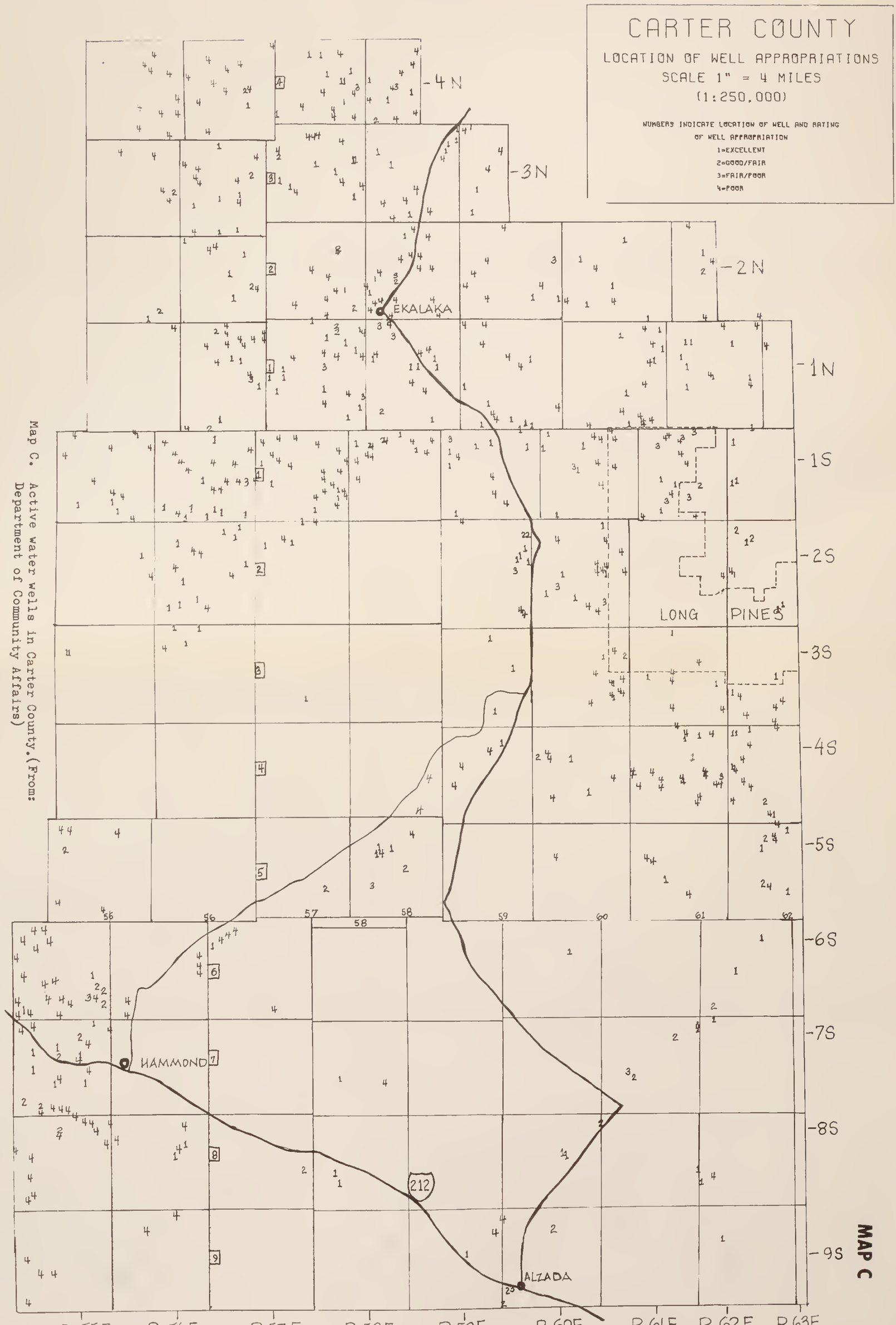
Map A. Uranium lands of the Northern Plains and types of activity.



Map B. Uranium companies and exploration in Carter County.

1977 URANIUM EXPLORATION ACTIVITY IN CARTER COUNTY -- EXXON HAD NO 1977 ACTIVITY (1976 ACTIVITY SHOWN)

MAP B



Map C. Active water wells in Carter County. (From: Department of Community Affairs)

MAP C